THE INSTALLATION OF ELECTRIC LIGHTING AND HEATING

THE INSTALLATION OF ELECTRIC LIGHTING AND HEATING

BY

FREDERIC H. TAYLOR

A.M.I.E.E., A.M.I.MECH.E.

MEMBER OF THE ILLUMINATING ENGINEERING SOCIETY OF LONDON
HEAD OF THE DEPARTMENT OF ELECTRICAL TECHNOLOGY AND ELECTRICAL INSTALLATION WORK AT THE WILLESDEN POLYTECHNIC

LONDON

CHAPMAN & HALL, LTD.

11 HENRIETTA ST., COVENT GARDEN, W.C. 2

1928

PRINTED IN GREAT BRITAIN
BY THE ABERDEEN UNIVERSITY PRESS
ABERDEEN, SCOTLAND

AUTHOR'S PREFACE

THE subject of Electrical Installation Work has long since needed a comprehensive and up-to-date treatise dealing with its many details in a practical way and free from unnecessary theory.

It is hoped that the method of treatment adopted in this book whilst undoubtedly novel will be found to be of direct utility. Much of the information given has not hitherto been included in the literature of the subject, and represents the results of long and practical experience. Special attention has been given to details of workmanship as well as to the essential points in the accessories and material used, from which alone good quality, safety and efficiency can be obtained. The necessity of efficient earthing and the proper testing thereof has been specially emphasised in view of its growing importance and the probability of further regulations in the near future. For the sake of completeness, Tables I. to VIII. of the Regulations of the Institution of Electrical Engineers have been included as an Appendix, and many extracts from these Regulations are given to amplify the text. A study of the book will be rendered even more profitable if reference is made from time to time to these Regulations as well as to those of the Home Office and to the Specifications of the British Engineering Standards Association.

My thanks are due to the Institution of Electrical Engineers for permission to include the tables in the Appendix, to the various manufacturers for their assistance with electros, and to my assistant, Mr. F. A. Tuck, for the preparation of the many diagrams.

FREDERIC H. TAYLOR.

19 OLD QUEEN STREET,
WESTMINSTER, S.W. 1,
May, 1928.

CONTENTS

SECTION I.—CONDUCTORS.

CHAPTER I. V.I.R. CONDUCTORS.

CHAPTER II. PAPER INSULATED AND AERIAL CONDUCTORS.

CHAPTER III. CURRENT DENSITY AND VOLTAGE DROP.

SECTION II.—SYSTEMS OF WIRING.

CHAPTER IV. STEEL CONDUIT SYSTEMS.

CHAPTER V. METAL CASED WIRING SYSTEMS.

CHAPTER XV. FUSES AND DISTRIBUTION BOARDS.

CHAPTER XVI. MAIN FUSES AND SWITCHES.

SECTION IV.—THE TESTING OF A COMPLETED INSTALLATION.

CHAPTER XVII.

SECTION V.—THE PLANNING OF A LIGHTING INSTALLATION.

CHAPTER XVIII.

SECTION VI.—ELECTRIC HEATING AND COOKING.

CHAPTER XIX.

SECTION I.

CONDUCTORS.

CHAPTER I.

V.I.R. CONDUCTORS.

In order that electrical energy may be conveyed to the required positions in a building for lighting, heating, or power, a system of current carrying conductors has to be provided. These conductors are almost exclusively of the class known as 'Vulcanised India Rubber.' The wire or wires contained within the conductor will be composed of soft tinned copper, covered with several layers of material, these being in the following order:—

(1) Pure rubber next to the copper.
(2) 'Separator,' or lightly vulcanised rubber.
(3) Vulcanised rubber.
(4) Rubber coated tape.
(5) An outside braiding treated with a waterproofing compound.

The first three materials may be regarded as the real insulation of the conductor, the remaining two layers acting mainly as mechanical protection. The tinning on the copper wires serves to protect them from corrosion, which might otherwise occur, by reason of the sulphur contained in the vulcanised rubber.

Stranding.—In practice, the majority of the conductors used are stranded; that is to say, they are composed of a number of wires instead of one solid one, the reason being that, when stranded, the conductor is much more flexible than a solid conductor would be, if of equivalent sectional area. The strandings adopted are: 1, 3, 7, 19, 37, 61, 91 and 127.

Sizes.—In the new standard sizes of conductor, each individual wire is described by its diameter; thus, a 1 / ·044 conductor is one consisting of one strand of wire, diameter ·044 inch.

Similarly, a 7 / ·064 would consist of 7 strands, each of ·064 inch in diameter.

The minimum size of conductor permissible (except for the wiring of fittings) is 1 / ·044 inch.

Insulation Grades and Class.—For the purpose of considering their insulation value, V.I.R. conductors may be grouped under two heads: the 'C.M.A.' Grades, and the Non-Association Class. The 'C.M.A.' (or Cable Makers' Association) Conductors, which are regarded as superior to those of the Non-Association (N/A) class, are made up in three grades; that is, the 300, the 600, and the 2 500 megohm grade. In each case the figure (or megohm grade) given signifies that the *largest* conductor of the series which is made under its heading, will have a guaranteed insulation resistance, per mile length, of not less than that figure. The smaller conductors of the series will have an insulation resistance considerably in excess of the nominal figure.[1] The examples given in the following table illustrate this point:—

C.M.A. Conductors.

600 Megohm Grade.		2 500 Megohm Grade.	
Size of Conductor.	Minimum Insulation Resistance Per Mile. (Megohms.)	Size of Conductor.	Minimum Insulation Resistance Per Mile. (Megohms.)
1 / ·044	2 000	1 / ·044	5 000
7 / ·029	1 250	7 / ·029	4 500
19 / ·064	750	19 / ·064	3 000
37 / ·064	600	37 / ·064	3 000
127 / ·103	600	127 / ·103	2 500

The same results obtain with Non-Association Conductors which, however, are made in one class only, *i.e.* 600 megohms.

Choice of a V.I.R. Conductor.—Where it is desirable to instal a high-grade conductor which will maintain its dielectric resistance throughout a long life, one of the Association grades

[1] It should be noted that the insulation resistance of a conductor varies inversely as the length: thus, if a mile length of a given size showed 2 000 megohms a 330-yard length would show—

$$\frac{2\,000 \times 1\,760}{330} = 10\,666{\cdot}6 \text{ megohms.}$$

will, naturally, be selected. For working pressures up to 250 volts, good results may be obtained with 600 megohm grade conductors. The difference in first cost, however, between this grade and the 2 500 is so small, that many engineers would prefer to use the latter.

For conditions where a low initial cost is of more importance than long life, Non-Association Conductors are very commonly used.

Cables which are the best of their kind should, in any case, be chosen. Inferior ones can readily be made which may show a high figure of test to begin with, but whose life may be comparatively short, as a result of the quality of the materials used to form the insulation.

C.M.A. and N/A Distinction Between.—In order that a ready distinction may be possible between these two qualities, a distinguishing label will always be found attached and sealed to every coil of wire. On each label is given the guaranteed Insulation Resistance per mile, after 24 hours' immersion in water at 60° Fahrenheit, and one minute's electrification, together with the length, size and class of conductor. As a further precaution, the description, whether Association or Non-Association, together with the maker's name, is now printed continuously along the tape, which is lapped over the vulcanised rubber insulation.

Characteristics of a Good V.I.R. Conductor.—The ordinary user who is not versed in the technicalities of cable manufacture will find the following points of assistance when examining a V.I.R. conductor for its quality :—

1. The copper conductor should strip 'clean,' that is to say, the stripping should leave a clean, well-tinned surface, slightly yellowish in colour.

2. The rubber strip should stretch to at least twice its length and, when released, return to its original length.

3. (*a*) The layers of vulcanised rubber should be well amalgamated.

(*b*) When dented by the thumb-nail, no permanent impression should be left.

(*c*) The vulcanised rubber should withstand being bent round a rod of its own diameter without showing any sign of cracking.

(*d*) Its surface should be free from specks of embedded material.

4. The tape should be of tough texture, and marked with the maker's name, and the grade or class.

5. The braid should be tight, of closely woven mesh, and well impregnated.

Lengths of V.I.R. Conductors.—Although, of course, any length is obtainable, it is usual for manufacturers to supply these conductors in coils of 100 yards. They are priced per 1 000 yards, although the guaranteed insulation resistance is still quoted at per mile of length.

Colours.—All V.I.R. conductors have their braidings coloured either red or black. The object of this is to assist in the distinction of polarity, red being commonly regarded as the sign of positive polarity, and black as negative. It is usual, for example, for all single pole lamp switches to be connected on either side with red conductor.

Temperature Limits for V.I.R. Conductors.—It should be noted that V.I.R. conductors should not be allowed to reach a permanent temperature greater than 120° F. for lengthy periods, nor more than 130° F. for short periods, otherwise premature deterioration may occur. For special positions where the temperature would be likely to exceed these limits, it would be necessary to select some other description of conductor.

Electrolier Wire.—For the wiring of electroliers, and in other cases where the overall diameter of the conductor used must be as small as possible, a special kind of V.I.R. conductor is used, which is known as 'Electrolier Wire.' This is made to the standards of the Cable Makers' Association, but its insulation is very much thinner than that of the ordinary V.I.R. conductor. It is braided externally, but not taped. The following table gives the four sizes which are made :—

Conductor.	Nominal Area in Sq. In.	Approximate Overall Diameter in Ins.
1 / ·036	·0010	·115
1 / ·044	·0015	·122
3 / ·029	·0020	·140
3 / ·036	·0030	·156

Flexible Cords.—Where connection is to be made to pendant or portable lamps, etc., flexible conductors (more often referred

to as 'flexible cords') become necessary. These are made up differently to the 'hard' or 'fixed' conductors, and in order to ensure flexibility, consist of a number of wires of very small diameter. The sizes in general use, together with their current carrying capacities, are given in the following table:—

Number and Diameter of Wires Forming the Conductor.	Nominal Area in Sq. In.	Maximum Current Permissible Under I.E.E. Regulations.	Maximum Current at Density of 1 000 Amps. Per Sq. In.
14 / ·0076	·0006	1·2	·615
23 / ·0076	·001	2·0	1·01
40 / ·0076	·0017	3·6	1·7
70 / ·0076	·003	6·2	3·0
110 / ·0076	·0048	10·0	4·8
162 / ·0076	·007	12·0	7·0

Flexible cord is made in many varieties, to meet the different conditions under which it is required to be used.

Twisted Twin Flexible Cord.—The ordinary cheap variety of cord consists of:—Two conductors formed of soft copper wires insulated with one coat of vulcanised rubber only, finished with a braiding of silk or cotton, the two conductors being then twisted together, so as to form a pair.

A much superior variety of cord is that known as 'C.M.A.' In this quality, the conductors are of *tinned* copper wires, insulated with a coat of pure rubber, then two coats of vulcanised rubber, and finished with a braiding of silk or cotton. The maker's test pressure for this cord is 1 000 volts alternating, applied for fifteen minutes. Where a maximum of flexibility is desired, and the position is a really dry one, 'pure rubber' flexible is often used. In this the conductors are of *plain* copper wires, lapped with cotton, insulated with two coats of pure rubber, again lapped with cotton, and finished externally with a braiding of silk or cotton.

Circular Flexible Cords.—Under the Regulation of the Institution of Electrical Engineers,[1] twisted twin flexible cords may only be used for fixed fittings and portable lamp standards. In all other positions and for all other purposes flexible cords of a circular or oval section must be used. The more commonly used classes of circular flexible cord are:—

[1] Regulations for the Electrical Equipment of Buildings, 1927. No. 81 A.

(*a*) **'Workshop' Flexible.**—This is made up in the same way as the ordinary vulcanised, or the ordinary pure rubber cord, the two conductors being then twisted together, padded circular, taped, braided overall, and finally served with a black-waterproofing compound. As its name implies, this cord is intended for workshop or factory pendant lamps. Naturally, it is not suitable for running over pulleys.

(*b*) **Whipcord Braided.**—This follows the same description as the vulcanised 'workshop' flexible, except that it is made circular with jute wormings, and then strongly braided with whip-cord, before being finally served with waterproofing compound. It is very robust in character, the whip-cord braid forming a good hard non-metallic armouring.

(*c*) **'Cab-tyre' Flexible.**—This special class of flexible consists of two vulcanised conductors, twisted together and then sheathed with a hard vulcanised rubber of a specially tough and durable quality. This sheathing is regarded as both acid and oil-resisting, and it forms an excellent non-metallic armouring.

(*d*) **Copper and Steel Wire Flexibles.**—Where the conditions of service require great mechanical strength as well as flexibility, the flexible cord is now being made up in the following manner:—

The conductor formed of both tinned copper and tinned steel wires, cotton-covered, insulated with vulcanised rubber, made circular with cotton wormings and braided cotton overall. A cord of this description would be suitable for such purposes as electric irons, radiators, cooking apparatus, portable electric tools, etc. For extra heavy service, where still greater mechanical strength is desirable, the flexible cord is sometimes entirely made up of tinned steel wires, insulated in a similar manner to the foregoing. Where necessary to make the flexible cords as fire-resisting as possible, asbestos wormings and also asbestos braidings are used in place of cotton.

Earthing Core Flexible Cords (3 Core).—The Home Office Regulations[1] covering the use of electricity in factories, require that where there is risk of a person receiving a shock when handling portable apparatus or pendant lamps through the exposed metal-work thereof becoming charged, then such metal-work must

[1] Regulation 13 / 1924.

be efficiently earthed. To this end, it is necessary, in such cases, to use flexible cord which contains an 'earthing conductor.' This (the third core) consists of tinned copper wires, insulated from the 'live' or current carrying wires. It is connected at one end to the apparatus, or part to be earthed, and at the other to something which forms a good and certain connection with the general mass of the earth. Further reference to the subject of earthing will be found in Chapter IV.

CHAPTER II.

PAPER INSULATED AND AERIAL CONDUCTORS.

THE paper insulated conductor is made up in the following manner: of soft, plain copper wires, covered with a high-grade insulating paper, impregnated with an insulating compound, and wound in strips spirally upon the conductor in two or more layers to the required thickness. Over the paper is drawn a sheath of soft lead, thus sealing the insulation from the atmosphere.

No rubber being used in the insulation, tinning of the copper wires of the conductor becomes unnecessary.

All paper insulated conductors are essentially lead covered, in order that the insulation may be permanently and hermetically sealed. It is imperative that this sealing should always be maintained intact. Thus, when the cables are being laid or fixed, a cut end must always be kept sealed by soldering over the sheathing, or by wiping a lead cap on to the sheathing. Likewise, all joints must be completely enclosed in compound-filled watertight sleeves or boxes, and all ends at terminals, etc., must be sealed by means of special fittings, to prevent the entry of atmospheric or other moisture. Junction boxes for making the usual connections between paper insulated and V.I.R. conductors are referred to under the heading of 'Underground Mains' (Chap. VII)..

Paper insulated cables are especially useful as underground feeders, or as main feeders or distributors in industrial installations; either above or below ground. Their long life and relatively low cost, compared with V.I.R. cables, are a strong recommendation.

Temperature Limits of Paper Insulated Cables and their Relative Current Carrying Capacity.—The temperature limit with paper insulated cables is appreciably greater than with V.I.R., the maximum permanent temperature allowable being 176° F. Consequently, therefore the current carrying capacity is (subject always to voltage drop) very much greater than in V.I.R. con-

ductors of equal cross-sectional area. The following table of comparisons of a few selected sizes, as published in the Regulations of the Institution of Electrical Engineers, 1927 (Tables IV. and V.) will serve to illustrate this point :—

Size of Conductor.	Current Carrying Capacity (Subject to Voltage Drop).	
	Paper Insulated.	V.I.R.
3 / ·036	12	12
7 / ·044	42	31
7 / ·064	75	46
19 / ·064	135	83

Aerial Conductors.—This class of conductor, as its name implies, is intended for outdoor use overhead, being supported from wood or iron poles, or brackets, to which porcelain insulators have been attached. For such duty the conductors may be either (*a*) plain, bare hard-drawn copper wire, single or stranded, or (*b*), as in (*a*), but covered with one or more layers of tarred jute braiding, impregnated with weather-resisting compound. The braiding is, in any case, intended to be a protection against the action of the weather, rather than an insulator; and, if well applied, forms also an effective deterrent against the corrosive action due to the pollution of the air in the neighbourhood of factories.

Where the distance between the points of support is considerable, or the section of the conductor heavy, 'span' or 'bearer' wires of galvanised steel are used, from which the conductor is hung by means of raw-hide suspenders.

CHAPTER III.

CURRENT DENSITY AND VOLTAGE DROP.

Conductors and their Current Density.—In order to determine the correct size (or section) of conductor to be used for a given 'load' or current to be carried, it is necessary to first decide upon the 'current density' which shall be allowed. By the expression 'current density' is meant the amount of current per square inch of cross-sectional area of the conductor. Should the current density be increased beyond the appropriate amount, two effects may arise: (*a*) heating of the conductor, and (*b*) an appreciable loss or 'drop' in pressure along the conductor, from one end to the other.

The 1 000 Ampere Rating.—A current density which it is very easy to adapt in many cases is that of: *1 000 amperes per square inch of cross-sectional area of the conductor.* At this density, no appreciable rise in temperature of the conductor will occur. This condition is, of course, essential from a fire-risk point of view.

Under the Regulations of the Institution of Electrical Engineers, a much larger current density than 1 000 amperes per square inch is permitted on all the more generally used sizes of conductor. In these Regulations the permissible current density has been settled according to the temperature which the conductor is likely to reach with a given current flowing. The density, therefore, is appreciably higher in the smaller sizes than in the larger, for the reason that the overall circumference (or cooling surface) does not increase in direct proportion to the cross-sectional area of the conductor. The following comparison will illustrate this:—

Size of V.I.R. Conductor.	Sectional Area (Sq. Ins.).	Overall Circumference (Ins.).	Current-Carrying Capacity I.E.E. Rating (Amps.).	Current Density (Amps. Per Sq. In.).
1 / ·044	·0015	·6754	6·1	4 000
7 / ·044	·01	1·008	31	3 100

In the accompanying Table is shown the current-carrying capacity of the more commonly used sizes of V.I.R. conductor, at 1 000 amps. per square inch density, and also that allowable under the Regulations of the Institution of Electrical Engineers, dated June, 1927 :—

Area of Conductor (Sq. Ins.).	Number and Diameter in Ins. of Wires Comprising the Conductor.	Current-Carrying Capacity.	
		At 1 000 Amps. Per Sq. In., Current Density.	Under I.E E. Regulations (Maximum Permissible).
·0015	1 / ·044	1·5	6·1
·033	3 / ·036	3·0	12·0
·0045	7 / ·029	4·5	18·2
·007	7 / ·036	7·0	24·0
·01	7 / ·044	10	31·0
·0145	7 / ·052	14·5	37·0
·0225	7 / ·064	22·5	46·0
·04	19 / ·052	40·0	64·0
·06	19 / ·064	60·0	83·0
·075	19 / ·072	75·0	97
·10	19 / ·083	100·0	118

The latter figures (Column 3) are intended to apply to 'single cables run in pairs in iron conduits, or in wood casings, and to single cables sheathed with tough rubber compound.'

Voltage Drop.—The voltage drop, or loss of pressure which must inevitably occur in any conductor carrying a current must be taken in consideration when the size of the conductor, and therefore its current density, has to be settled. This drop in volts will be directly proportional to (*a*) the current carried, and (*b*) the resistance of the conductors carrying it; or

$$E = I \times R,$$

where E, I and R stand for volt-drop, current and resistance respectively.

In view of the fact that the drop is proportional to the resistance of the conductors, it follows that it is proportional to their total length, assuming, of course, that they are of uniform section throughout.

The two following examples will serve to illustrate the calculation of voltage drop from the formula already given:—

(1) The resistance of a certain length of cable is said to be

·005 ohm. What will be the loss of pressure therein if the current flowing is 210 amperes ?

$$E = I \times R.$$

Therefore $$E = 210 \times \cdot005 = \underline{1\cdot05 \text{ volts.}}$$

(2) A number of lamps fed from a distribution board require a total current of 10 amperes. The distance from this distribution board to the source of supply is 200 yards. What will be the drop in volts in the cables which run from the source of supply to the distribution board, if their resistance is 2·36 ohms per 1 000 yards ?

If the resistance of 1 000 yards = 2·36, then the resistance of 400 yards (total length) will be

$$\frac{2\cdot36 \times 400}{1\ 000} = \cdot94 \text{ ohm.}$$

Then, if $E = I \times R$,

$$E = 10 \times \cdot94 = \underline{9\cdot4 \text{ volts.}}$$

Calculation of Sectional Area of Conductors.—In the foregoing examples, the resistance of the conductors in ohms was given. This is not always so, and it may therefore be necessary to obtain this value from tables such as are usually given in the catalogues of the principal cable manufacturers, or, alternatively, to calculate it from the formula

$$R = \frac{L}{A} \times S,$$

where R is the resistance expressed in ohms,
,, L ,, length expressed in inches,
,, A ,, cross-sectional area expressed in square inches,
,, S ,, specific resistance of the material of the conductor per inch cube.

(*Note.*—The specific resistance of copper may be taken as ·66 microhm per inch cube.)

The formula is, however, a little cumbersome to handle, and in general practice it is more convenient to apply the rule for copper conductors, that—

At a current density of 1 000 amperes per square inch, the pressure drop will be $2\frac{1}{2}$ volts per 100 yards of total length of the conductor, or 1 volt per 40 yards of total length. The following example (Nos. 3 and 4) will show its practical application.

(3) Find the cross-sectional area of the conductor necessary to convey a current of 50 amperes to a point 200 yards away, if the pressure drop is not to exceed two volts.

If the current density were 1 000 amperes per square inch, and the current were 50 amps., the sectional area would be

$$\frac{50}{1\ 000} = \cdot 05 \text{ sq. inch.}$$

This would give $2\frac{1}{2}$ volts drop per 100 yards, or

$2\frac{1}{2} \times 4 = 10$ volts drop for the *total* length of 400 yards.

As the pressure drop must be 2 volts only, the sectional area must be

$$\frac{\cdot 05 \times 10}{2} = \cdot 25 \text{ sq. inch.}$$

The standard size of conductor of this area is: 37 / ·093 inch.

(4) A pair of conductors have to be taken a distance of 120 feet, to supply 8-100 watt lamps, at a pressure of 200 volts. What must be the size of conductor if the pressure drop is not to exceed 1·5 volts?

$$\text{Total load} = 8 \times 100 = 800 \text{ watts.}$$

$$\text{,, current} = \frac{800 \text{ watts}}{200 \text{ volts}} = 4 \text{ amperes.}$$

A conductor to carry 4 amperes at a current density of 1 000 amperes per square inch would have a sectional area of

$$\frac{4}{1\ 000} = \cdot 004 \text{ sq. inch.}$$

This would give a drop of $2\frac{1}{2}$ volts per 100 yards or

$$\frac{2 \cdot 5 \times 80}{100} = 2 \text{ volts,}$$

in the total length of conductor as given—

$$\frac{120' \times 2}{3} = 80 \text{ yards.}$$

Therefore the section required to give only 1·5 volts drop will be

$$\frac{\cdot 004 \times 2}{1 \cdot 5} = \cdot 0053 \text{ sq. inch.}$$

(The nearest standard sizes of conductor to this are: 7 / ·029, whose section is ·0045 sq. inch, or 7 / ·036 whose section is ·007 sq. inch.)

Effects of Voltage Drop.—It is essential that the pressure drop in any circuit be kept reasonably low. This is particularly needful if the load be a lighting one, for the reason that a small decrease in the voltage will result in a relatively large decrease in the candle-power given out by the lamp. It is said that in the modern gas-filled lamp, a 10 °/ₒ increase in the voltage is equivalent to about 39 °/ₒ increase in candle-power of the lamp.[1]

The Regulations of the Institution of Electrical Engineers prescribe that for lighting, the fall in pressure from the consumer's terminals to any and every point does not exceed one volt plus 3 °/ₒ of the pressure at the consumer's terminals, when the conductors are carrying the maximum demand under the practical conditions of service. This regulation is, undoubtedly, a very generous one, and in any well-designed installation the pressure drop should be nothing like as high as this.

Distribution of the Voltage Drop.—In the design of an electrical installation it is a matter for careful consideration as to how the maximum allowable voltage drop may best be distributed over the various conductors as represented by the mains or feeders, the sub-mains or feeders, and the 'point-wiring' from the distribution boards.

Practical experience indicates that in the majority of ordinary lighting installations, it is wise to allow not less than one volt drop in the point-wiring. This, it should be noted, is not entirely accounted for by the 'copper resistance.' It is, to a considerable extent, represented by 'contact resistance,' that is, the resistance set up at numerous contacts occurring at switches, lamp-holders, ceiling roses, fuses, plugs, etc.

The apportioning of the drop in the mains and the sub-mains will, to some extent, be governed by their respective lengths and costs in the particular case under consideration.

[1] *Illuminating Engineering*, by Cady and Dates.

SECTION II.

SYSTEMS OF WIRING.

CHAPTER IV.

STEEL CONDUIT SYSTEMS.

In all interior installation work it is usual to enclose the conductors in some way which shall protect them from possible injury. Many systems have been devised, but it cannot be said of any one system of wiring that it is the best for any and every conceivable kind of job. In order to arrive at a correct decision, each case must be considered in the light of its own special circumstances. Any system, however, to be efficient, should be as proof against water, dampness, or mechanical injury as possible. There should likewise be no risk of fire, or of any possibility of shock to the person.

Steel Conduit Systems.—In each of these systems the V.I.R. conductors are either passed or drawn in to specially made steel tubes; appropriate iron boxes or other pipe fittings and accessories being used to complete the system. The several classes of steel conduit, as now used, may be classified as follows:—

(A)

'Light Gauge' or plain conduits (unscrewed) { 'Close' joint (*i.e.* butt joint). Brazed. Solid drawn.

(B)

Heavy Gauge (all screwed connections) { Welded. Brazed. Solid Drawn.

Conduits of the 'A' class are used for what is known as 'slip-socket' work. Each length of conduit has a plain or unscrewed end, the connection or joint between one length and another being made by means of a plain (unscrewed) coupling or

socket. The pipe fittings, such as boxes, bends, tees, etc., will also, of course, be of the plain or unscrewed pattern. The 'close' joint conduit is a tube having an open seam, and cannot, therefore, be water or damp-tight. Fig. 1 shows a section of this. Obviously, it cannot be bent without either opening or crushing in. The use of brazed or solid drawn plain conduit with 'slip-socket' joints, whilst being an improvement on the foregoing, and permitting of bending, will not provide a water-tight system.

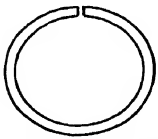


FIG. 1.—Slip-socket conduit (close joint).

Conduits of the 'B' class, being made of a much heavier gauge of metal, are provided with screwed ends and, of course, are connected together by means of screwed couplings. All the pipe-fittings are similarly arranged for screwed connection. Under this system it is possible to provide for complete watertightness throughout, and any of these three varieties of conduit can be readily bent cold to any required angle.

Comparison of the Several Types of Steel Conduit.—Of the 'slip-socket' systems referred to under class 'A' conduits—the close joint variety cannot be advised, if good quality work is required. Its use is not favoured by Fire Insurance and other authorities. The risk of its seam either opening or crushing due to even a slight bend or set is a serious one. It should never be allowed to be sunk under plaster work. The brazed and the solid-drawn varieties have the one advantage of suitability for bending. It should be noted that plain slip-sockets do *not* conform with the Regulations of the Institution of Electrical Engineers, some form of screwed or grip joint such as will ensure 'ample and permanent electrical conductivity and mechanical rigidity throughout' being absolutely necessary.[1]

Of the class 'B' conduits for screwed work, the solid-drawn variety is the highest grade of conduit obtainable, being free from any possibility of defects in the way of internal roughness, and being also the most easily bent.

Bending and Setting of Conduit.—All the ordinary sizes of conduit are bent 'cold.' The operation is one that is readily performed, owing to the steel being comparatively 'mild.' Although

[1] Regulation 87, Class T. 2.

various patterns of pipe-bending machines are obtainable, the more usual method is by means of a block of wood in which a circular hole has been drilled, through which hole the piece of conduit to be bent is passed. A steady pressure applied at one end by the operator will enable the necessary bend or set to be formed. When made, a bend must be free from any flattening of the surface of the conduit, or other departure from a truly circular form. This condition is only likely to be attained if the bend or set is formed gradually, that is to say, by a series of thrusts, instead of by one sustained thrust. When bending a piece of brazed or welded conduit, it is preferable to keep the seam at the side, rather than to attempt to make the bend with the seam on the top or on the inside of the curve. Care should be taken to see that the piece of conduit selected for bending has its seam running straight, that is, along a line parallel with the side of the conduit. It is hopeless to bend conduit in which the seam travels round the circumference. Such material should be rejected as defective.

Cutting Threads.—When cutting a thread on the end of a length of conduit, a fairly generous application of oil is necessary. The newly cut thread should, however, be wiped clean before inserting the conduit into the socket or other fitting. In order to assist in maintaining watertightness, some fitters are inclined to apply red lead paint. It is, however, very much better to employ aluminium paint for this purpose.

'Continuity-Grip' Fittings for Class 'A' Conduits.—For systems using this class of conduit some device is necessary in order to ensure that every length of conduit and all conduit fittings are electrically continuous throughout, and also that they are mechanically connected in a permanently rigid manner. Electrical continuity is essential in order that the whole of the conduit work may, on the completion of its erection, be 'earthed' at one or more points.

Mechanical rigidity is likewise necessary, as, otherwise, the several lengths of conduit may, by vibration, become loosened from one another, or from the conduit fittings. In such cases, proper protection of the conductors is not obtained. Of the many different designs of 'continuity-grip' fittings, two may here be mentioned:—

(*a*) **The 'Walsall' Grip Fitting.**—Fig. 2 shows the principle of the Walsall Grip as applied to an ordinary inspection

type of elbow. It will be noted that each end of the fitting is provided with lugs and that close up to these a narrow slit or saw-cut is provided, which passes round about half the circumference of the fitting. A length of conduit having been inserted into the end, the screw is then tightened up, making a thoroughly tenacious and metallic joint. The end of the conduit must, of course, be first scraped clean before being inserted into the fitting. The same principle is applied to the ordinary coupling and to all other fittings.

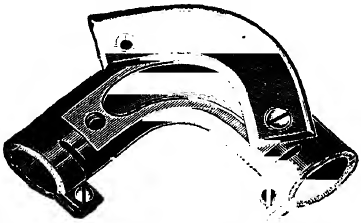


FIG. 2.—'Walsall' grip continuity fitting.

(*b*) **The Simplex 'Terra-grip' Fitting.**—Figs. 3 and 4 illustrate the principle of this. Each end of every fitting has a boss drilled and tapped to receive the specially shaped screw shown in Fig. 3. The conduit having been inserted into the fitting, the screw is driven home. The cup-shaped end of the screw, on making contact with the conduit, will tend to expand, thus cleaning the surface and locking itself into position.

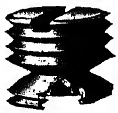


FIG. 3.—Special screw used in 'Terra-grip' fitting.

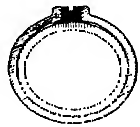


FIG. 4.—Section of conduit showing expansion of screw.

Protective Coatings for Conduit, etc.—All conduits and their various fittings are either black enamelled or galvanised, both inside and out, the object of such treatment being to ensure protection against corrosion. Internally, either treatment provides a smoother surface for the conductors to be drawn over, and in the case of black enamel, a slight addition to the insulation of the conductors.

Enamelling.—The black enamel with which conduits are commonly coated should be of the best quality, and, so far as possible, adhesive, non-porous, flexible, and permanent in character.

Galvanising.—This form of protection is essentially more proof against corrosion than enamelling, consisting, as it does, of a coating of relatively pure zinc on the surface of the steel. The cost is, naturally, very much greater than enamelling.

Painting of Conduit Work.—When the conduit work has to be concealed under the plaster of the walls, some additional treatment is necessary, if corrosion is to be avoided. This is due to the fact that, during transit, and in the course of handling and erection on the job, the enamel is liable to be scratched and injured, however good its quality. To prevent such corrosion, the conduit and its fittings should be painted at least two coats of good red oxide paint, after cutting and fitting, and before being fixed in position. The same treatment applied to galvanised conduit is also an advantage.

Where the conduit is run on the surface of finished walls and ceilings, it will naturally require to be painted to match the surrounding decorations. In this case particularly, it will be necessary for the conduit to receive a coat of 'knotting,' which shall be allowed to dry and harden before any paint is applied, otherwise the black will eventually show through and spoil the finish.

Selection of Conduit.—Class 'A' conduits are only suitable where the work is to be carried on the surface, and then only in positions where a watertight system is not imperative, and where low first cost is the chief consideration. For either surface or concealed work, any of the conduits under class 'B' are suitable. It must, however, be remembered that certain plasters and 'patent floorings' have a corrosive action on any *iron or steel*, and that where these are in use, metal conduit must be avoided.

Underground Work in Conduits.—It is sometimes necessary for wiring work to be carried underground. In this case any of the conduits under either of the classes given are unsuitable, the thickness of the metal of which they are made being insufficient. Wrought-iron pipe, such as is used for gas or water, should be selected, care being taken to see that it has been 'drifted out,' so as to present a perfectly smooth interior. Preferably, the pipe will be galvanised, and after being cut and fitted, receive two coats of good oil colour before being laid in position.

Fixing of Conduit.—Conduit is fixed by means of pipe-hooks,

saddles, or crampets. Pipe-hooks may be used for fixing the conduit on plain brickwork. Wiremen frequently resort to ordinary cut nails for this purpose, these being half driven in

FIG. 5.—Saddle for fixing conduit. (Walsall.)

FIG. 6.—Crampet for fixing conduit. (Walsall.)

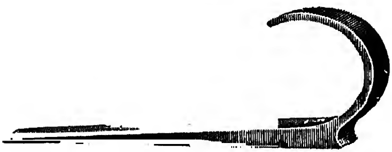


FIG. 7.—Pipe-hook for fixing conduit. (Walsall.)

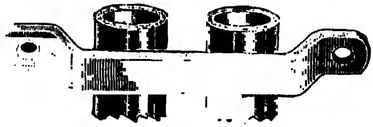


FIG. 8.—Multiple saddle for fixing conduits. (Walsall.)

and then bent over. Such a practice is to be deprecated. Saddles are for use on finished walls (of whatever material) and on woodwork or on plaster ceilings. Crampets (or half-saddles) are convenient where the conduit has to be fixed close in to the angle formed by two adjacent walls or a wall and a ceiling. Illustrations of these accessories are shown in Figs. 5, 6, 7, and 8. Where conduit has to be run on glazed brickwork or tiling, it should not be fixed by ordinary saddles, so as to lie hard on the surface, but be packed out from same by means of 'spacing saddles,' so as to leave a clear space behind. The wall surface can then be washed down without injury to the conduit, and there is no lodgment for dirt and damp. Fig. 9 shows one of these saddles.

FIG. 9.—Spacing saddle for conduit. (Walsall.)

Conduit Sizes and Screw Threads.—It is customary with gas and waterpipes for the specified size to mean the *internal* diameter or bore. With electrical conduit, however, the specified size is the *external* diameter. The standard sizes in conduit are: $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$, and 2 inches. Although $\frac{1}{2}$-inch conduit is

obtainable, it is too small to be of practical use, if good workmanship is intended. In selecting a size of conduit to receive a given number of conductors, it is desirable to allow ample diameter, rather than use a size which is only just large enough. By this practice, the drawing-in of the conductors will be easier and quicker, and there will be least risk of injury to their insulation. The screw threads used for conduits and their fittings are special to this class of material, and are always known as 'conduit threads.'

Drawing-in of Conductors.—As it is not possible to draw the conductors round two or more bends, it is necessary to provide a 'draw-in' point at or near to where the change of direction of the conduit occurs. For instance, if it be required to draw the conductors through the run of conduit marked A, B (Fig. 10), it will

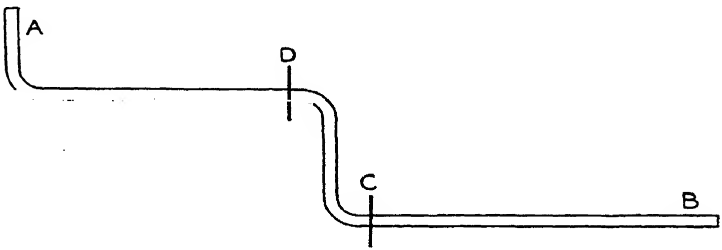


Fig. 10.—Illustration showing necessary 'draw-in' points.

be necessary to arrange for a draw-in point at, or near to C and D. These may take the form of a 'straight-through' box, which may be either circular or oblong, or an 'inspection elbow,' or an 'inspection bend.' An illustration of each of these fittings is shown in Figs. 11, 12, 13, 14, and 15. The cover of any one of these fittings being removed, the conductors can be eased round the adjacent bend.

All conduit fittings must be of the inspection type, if good work is to be done. Bends and sets in the conduit have to be made up on the job to suit the particular local conditions obtaining. Any conduit system should be so designed that the whole of the conduit and its fittings can be fixed first and the conductors drawn in afterwards. To facilitate the drawing-in where the run is unavoidably an awkward one, a 'fish-wire' is sometimes left in the conduit during erection, the conductors being temporarily attached to

this when they are to be drawn in. A piece of No. 16 S.W.G. galvanised iron wire is very useful for this purpose. An alter-

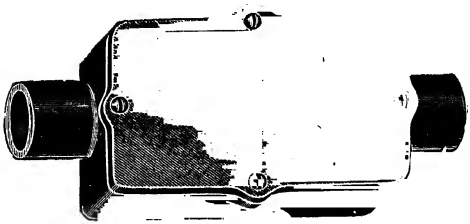


FIG. 11.—Straight-through draw-in box. (Walsall.)

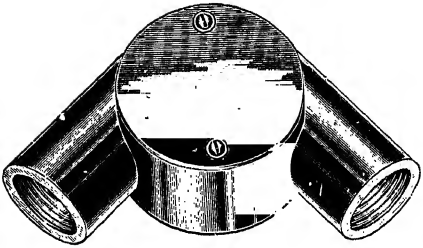


FIG. 12.—Inspection elbow. (Walsall.)

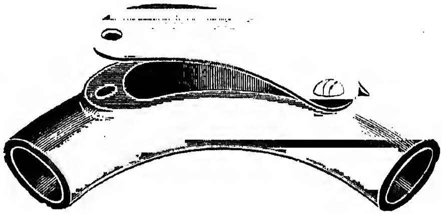


FIG. 13.—Inspection bend. (Walsall.)

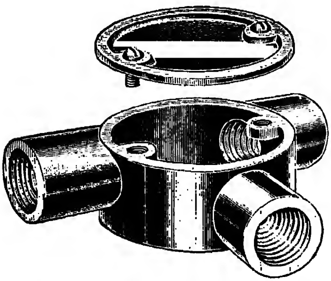


FIG. 14.—Inspection tee-piece. (Walsall.)

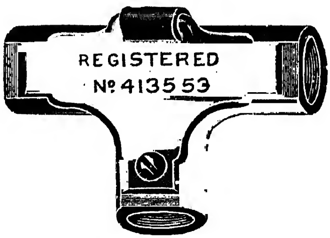


FIG. 15.—Inspection tee-piece. (Walsall.)

native method is to use a narrow steel tape which has a round blob on the end, so as to be easily pushed round the bends, the conductors being temporarily attached to the other end.

Watertight Fittings.—It is frequently necessary that the conduit system should be completely watertight. In this case the ordinary inspection fittings are not suitable, but to secure this condition, fittings of the inspection type having machined joints are obtainable from the leading manufacturers, and at no extra cost. No rubber or other packing is required. Some samples of these are shown in Figs. 16 and 17.

Lock-nuts, Bushes, etc.—The necessity of lock-nuts is frequently overlooked. When a conduit enters a metal fitting, such as a switch outlet, a distribution board, an iron-clad main switch, or fuse, etc., a clearance hole should be drilled in the same, the conduit passed through, and be lock-nutted on the outside and pre-

. 16.—Inspection Watertight bend. (Walsall.)

ferably fitted with a brass bush on the inside. This latter not only acts as a lock-nut, but provides a smooth edge for the conductors to be drawn over. An illustration of this is shown in Fig. 18. Wherever conductors emerge from a conduit, the end of the latter must be properly bushed, so as to provide a smooth outlet. In certain cases a 'short-end elbow' or a 'short-end T piece' is useful as an outlet, the end where the conductors leave being specially rounded, so as to obviate the use of a bush. An illustration of each of these two fittings is shown in Figs. 19 and 20.

'Bunching' in Conduit.—By the expression 'bunching' is meant the placing together in the same conduit of conductors of opposite polarity. This is quite permissible where the system of supply is by 'direct' current. Where, however, an 'alternating'

current system prevails, bunching of the conductors is absolutely essential. If this be not observed, a certain drop in voltage, due to inductance, may result.

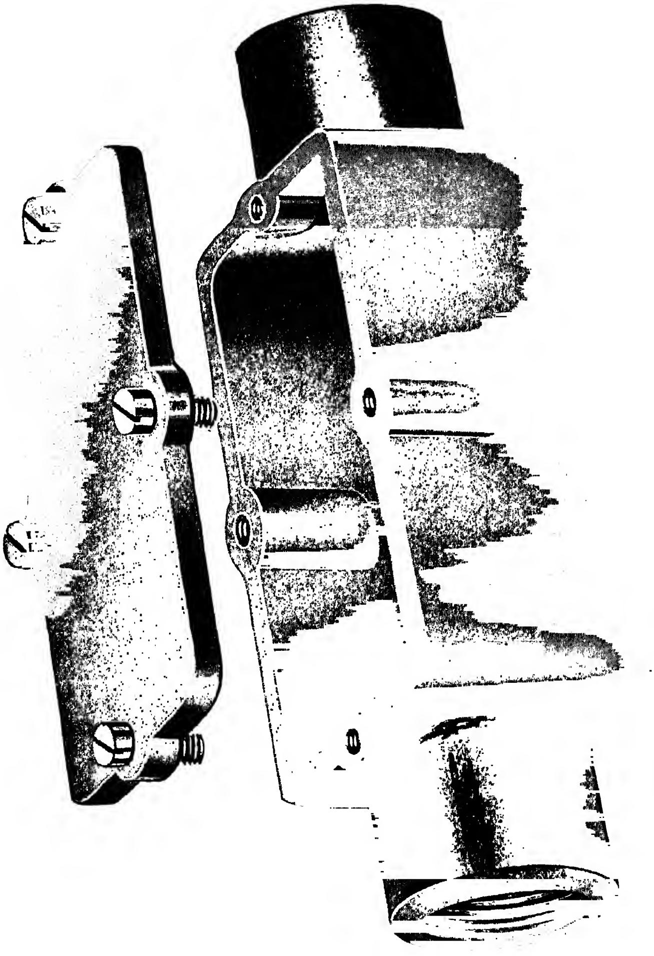


FIG. 17.—Inspection Watertight Box. (Walsall.)

Condensation.—Under certain circumstances, it is possible for condensation of moisture to take place inside the metal conduit,

unless proper precautions are taken to avoid it. Care must be exercised in selecting positions for the runs of conduit so that it is not exposed to wide variations of temperature. Also, when the conduit has been erected, it should be allowed to remain with its

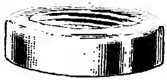


FIG. 18.—Brass bush for conduit end. (Walsall.)

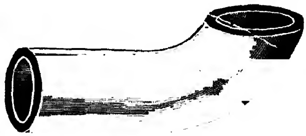


FIG. 19.—Short-end elbow. (Walsall.)

ends open as long as possible, previous to the conductors being drawn in. It may here be noted that the regulations of the Institution of Electrical Engineers suggest ventilating outlets at the highest and lowest points, in order to allow circulation of the air throughout the conduit (Rule 87, XXI.).

Earthing.—It is imperative that all conduit and other metal work connected to it should be earthed. The reason for this is to avoid risk of shock to the person, should one of the conductors, through damage or accident, become in contact with it, and to diminish the risk of fire. The necessity for proper earthing cannot be too strongly emphasised. Assuming that the conduit and all other metal-work has been made electrically and mechanically continuous throughout, the system will be earthed at one or more points in the following manner:—

FIG. 20.—Short-end tee. (Walsall.)

(*a*) **The Earthing Conductor.**—This will be connected at one end with the conduit system, and at its other end with something which forms a good and certain connection with the general mass of the earth. The material of the earthing conductor will be high conductivity tinned copper, and its sectional area will *be not less than* one-half of that of the largest conductor contained in the conduit, provided always that the minimum size of earthing conductor be not less than ·0045 sq. inch (7 / ·029). These are the regulations of the Institution of Electrical Engineers. It would, however, appear to the author that the earthing conductor might

well be of a section appropriate to the current it may be called upon to carry, which, of course, might be the current carried by the largest conductor contained in the conduit. In installations of considerable size, it may be desirable to earth the conduit and metal-work at more than one point. If this be done, it is desirable that these points should be efficiently and permanently connected together.

All earthing conductors should be adequately protected against mechanical injury. This means that they should be contained throughout their length in pipe or other form of casing.

It is usual, where there is but one main earthing conductor, that this is connected to the conduit system as near as conveniently possible to the point of entry of the electrical supply.

(*b*) **The 'Earth' Used.**—Where there is a public water supply, as is the case in all towns and urban districts, it is usual to 'earth' by making connection from the earthing conductor on to a live water-main. When this is chosen as the 'earth,' it is best to make the connection as near as possible to the main stop-cock, which is commonly found near to the point of entrance of the water-main. Cases sometimes arise where this method of earthing is not available: it may then be necessary to form an 'earth' by means of a copper earth plate buried in the ground. This earth plate should be of a size not less than 2 feet × 2 feet × $\frac{1}{8}$ inch thick, and it should be buried vertically in the ground at a depth of not less than 6 feet below the surface, the position chosen being a moist one. In order to retain the moisture around the plate, it is usual to surround it with a layer of well-washed coke or cinders. The earthing conductor should be connected to the plate by soldering, and the joint well washed before the plate is buried.

Local circumstances will often provide other means of earthing, as, for instance, the sinking of the earth plate in a lake, river, or dock, etc. Gas pipes, heating pipes, sewage pipes, or lightning conductors should never be used as 'earths.'

(*c*) **Connection of Earthing Conductor.**—Various patterns of 'earthing clip' or 'clamp' are available for making connection between the earthing conductor and the conduit, or, alternately, between the earthing conductor and a water-main. By far the most satisfactory form for either case is that shown in Fig. 21. The two parts of this are of wrought iron, and are machined on the inside, so as to offer a clean metallic surface to the conduit or the

water-main, which will require to be filed or scraped clean before the clip is applied. It is essential that the earthing conductor be connected to the clips, not by being twisted round the screw or bolt, but by means of a proper cable socket of sufficient size, so that all the strands of the conductor are contained within the socket to which they will be connected by soldering.

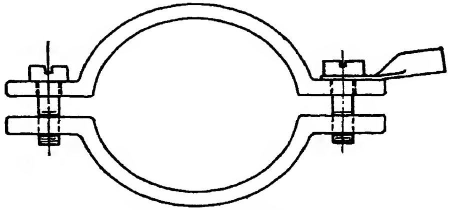


FIG. 21.—Earthing clamp.

All earth connections should be visible and readily accessible.

Resistance of Earthing.—The electrical resistance of the earthing as measured between any part of the conduit system and earth, must be kept as low as possible. There should be no difficulty in keeping this resistance down to such a value as one or two ohms, even where long runs of conduit are in use.

Importance of a Low Resistance Earth Connection.—The importance of keeping the resistance of the connection to earth as low as possible cannot be too strongly urged. If through improper design or workmanship this resistance should be unduly high, it will mean that should a leakage of current occur and go to earth via the defective earthing connection, there may be a very appreciable difference of potential between the conduit and earth, when it would consequently be possible for a person handling the conduit to receive a shock.

Testing of Earthing.—It is most necessary that all earthing arrangements should be tested. One method which is purely qualitative is to use an ordinary electric bell and a battery, and by making contact at various selected positions, to prove that each of these is in electrical continuity and in contact with earth. Fig. 22 will serve to make this operation clear. One end of the bell circuit (*i.e.* the wire from the battery) may be taken down to a temporary earth connection, such as a gas pipe, and the other end (*i.e.* a long trailing wire) can be used to make momentary contact with various parts of the conduit or other metal-work. Wherever this is done, the bell should ring, thus proving a complete circuit to earth. Unfortunately, this test is often accepted as a proof of good earthing, but this is, by no means, necessarily the case, as it can be shown by experiment that quite a good ring on an ordinary electric bell

can be obtained when the total resistance external to the bell is of the order of 15 to 20 ohms, and when using a four-volt battery.

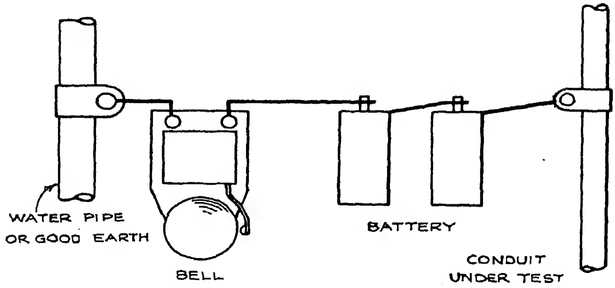


FIG. 22.—Method of taking continuity test for earthing.

Such a value as 15 ohms is obviously inadmissible for earthing purposes.

Other methods of testing will enable one to accurately measure the true value of the resistance of the earthing. The following examples will suffice:—

(*a*) By the means of a Wheatstone Bridge and a suitable portable galvanometer, the value in ohms can be obtained.

(*b*) By taking a volt drop test between selected points in the conduit system and earth. For this test, the following apparatus is required: a four-volt accumulator of say 20 ampere hours capacity, an ammeter and a low-reading voltmeter. By noting simultaneously the current passing and the volt-drop across the circuit, the resistance is calculated from the formula

$$R = \frac{E}{I},$$

where E and I are the volt drop and the current respectively. Diagrams illustrating the connections for these two methods of measuring resistance of Earthing are given in Figs. 23 and 24.

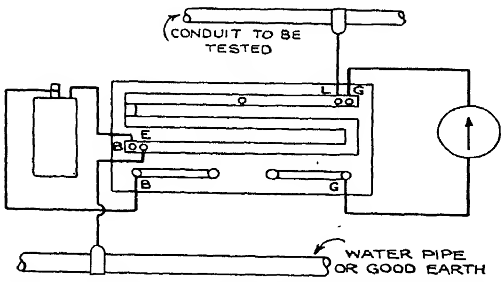


FIG. 23.—Method of taking Bridge test for earthing.

Method (*b*), although, perhaps, a little more troublesome, is often to be preferred to (*a*), as in large towns and cities a bridge test may become inconvenient, if not impossible, owing to the interference by stray earth currents from telephone or other circuits in the vicinity.

(*c*) Another method of testing, in localities where stray earth currents occur, is to employ an alternating current through the earth circuit. To meet this point, Messrs. Evershed and Vignoles have introduced the 'Earth-plate Tester,' which is illustrated in Fig. 25. In this instrument, a special commutator is used, which is interposed between the ohmmeter and the soil section of the testing circuit. By this means, an alternating current is provided for the earth, whilst direct current is used for measurement. The usual scale of the instrument is 0 to 30 ohms.

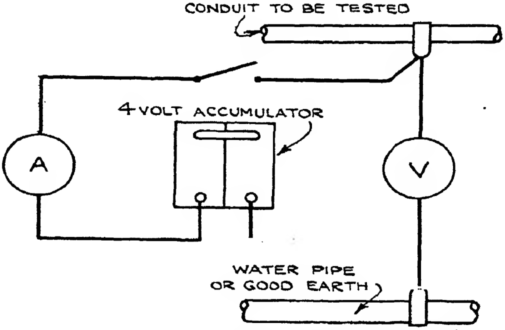


FIG. 24.—Method of measuring earthing resistance by volt drop test.

FIG. 25.—Evershed's earth-plate tester.

Isolating.—Equally necessary as good earthing would seem to be the isolating of all the electrical conduit work from girders, gas-pipes, etc., in fact, from everything which is conducting, so that the only path to earth is that provided by the earthing connection. If this practice be not followed, it is impossible to

properly test the earthing of the system; and also it should be noted that gas-pipes or other non-electrical metal-work may become 'live' in the event of a fault developing.

Points to be Noted in the Erection of a Conduit System.—1. The runs of the conduit to be kept as straight as possible, provided always that where the work has to be done on the surface, due regard be paid to its symmetrical appearance when finished.

2. Under floors, conduit is intended to be *fixed,* not merely laid to rest.

3. In positions where important 'draw-in' points occur under floors, traps should be left in the floor, so as to provide ready access, when required.

4. In installations where the Distribution boards are wood cased, care should be taken to bond across at these points all conduit, both incoming and outgoing. This may readily be done by soldering an earthing wire on to the brass bush with which each conduit terminates, and then stranding and soldering these several earth wires together.

5. Burrs or fins must everywhere be removed before assembling the conduit.

6. All the conduit to be left clean inside before the conductors are drawn in, and all superfluous oil to be wiped off the conduit threads, etc.

7. Screw threads must be well cut. Slack threads should, on no account, be permitted.

CHAPTER V.

METAL CASED WIRING SYSTEMS.

THE majority of the metal-cased wiring systems employ V.I.R. conductors sheathed with a special lead alloy, and they are therefore frequently referred to as 'lead-covered wiring.' The object of all these systems (which are mainly intended for surface wiring) is to obviate the use of steel conduit, or other form of casing, as a mechanical protection to the conductors.

The Henley Wiring System.—*The Conductors.*—In this system, the single conductors are of circular section, the twin and three-core cables being flat or oval. These latter are illustrated in Fig. 26. The conductors are formed of high conductivity

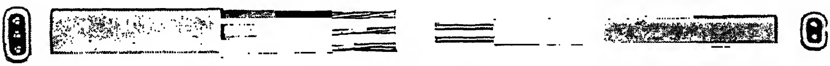


FIG. 26.—Henley twin and three-core conductors.

tinned copper wires, insulated, as usual, with pure and vulcanised india-rubber and taped with a waterproof tape coloured either red or black.

Grade.—Usually, these conductors are of the Non-Association class, but, if required, they can be obtained in the Association grades of 600 and 2 500 megohms.

Method of Fixing.—Before attempting to fix the conductors, the runs they are to follow should be marked out and the special clips which will hold them should be fixed in position. These clips will be spaced according to the position of the conductors to be carried, but will, in any case, be sufficiently close together to prevent any sagging. Usually, spacing from 9 inches to 15 inches apart will suffice. Figs. 27 and 28 show two types of clip in use for fixing one or two twin conductors. The manipulation of these is extremely simple. The conductor (or conductors), having been laid across the centre of the clips, which will already have been

fixed to the wall by brass pins, the two ends of the clip will be lifted up, and pinched together with pliers, the link slipped over

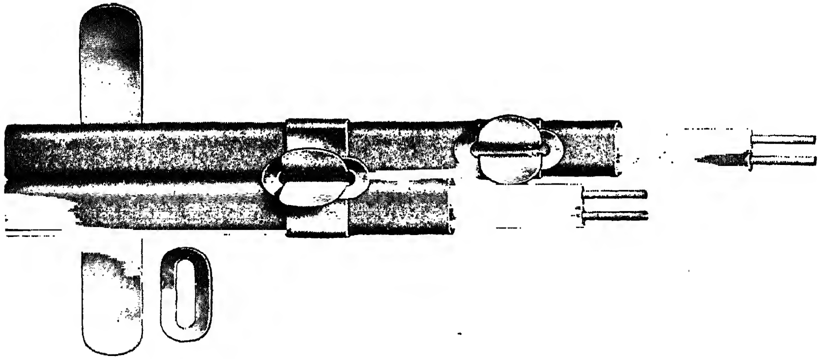


FIG. 27.—Henley link clip.

the two ends, which are then turned sharply back over the conductors. The clips are made of tinned brass, so as to minimise as much as possible any risk of corrosion due to electrolytic action between the lead sheathing of the conductor and its clip.

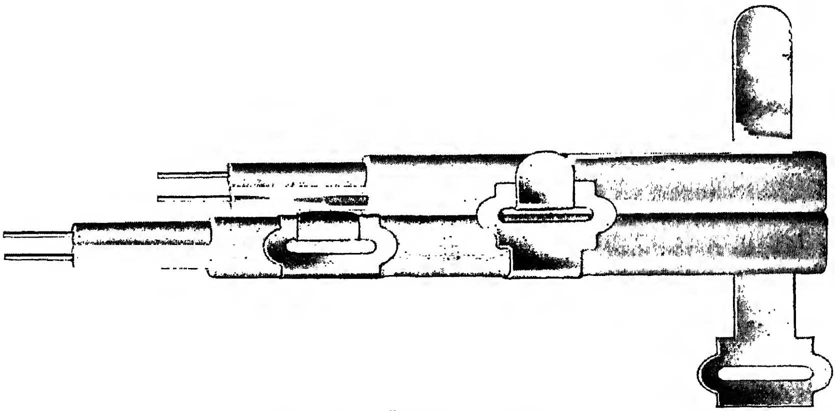


FIG. 28.—Henley strap clip.

Jointing and Bonding.—In this wiring system it is not convenient to adopt 'looping-in' of the conductors from one point to another to any great extent, as would be the case in a conduit system, owing to the necessity of opening the lead sheath of the

twin and triple conductors. Some kind of mechanical joint is therefore required. This is provided by means of china connectors, which are contained either in special junction boxes or, alternatively, concealed behind the wood block on the face of which the switch, ceiling rose, or other fitting, is fixed. Figs. 29 and 30 illustrate a single-way and also a two-way porcelain

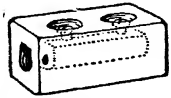


FIG. 29.—Single-way connector.

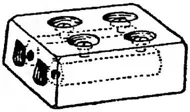


FIG. 30.—Two-way connector.

connector, and in Fig. 31 is seen two of the former and one of the latter in use in a Henley-Standard Tee-box. These china connectors may also be obtained in a three-way pattern. The junction boxes are of the split type and are manufactured in tinned brass, the continuity of the metal sheathing being preserved by means of double clamps that firmly hold down the lugs on the boxes to the lead sheathing of the conductors entering

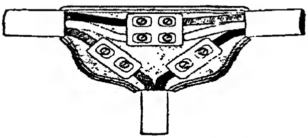


FIG. 31.—Henley tee-box with two single-way and one two-way connector.

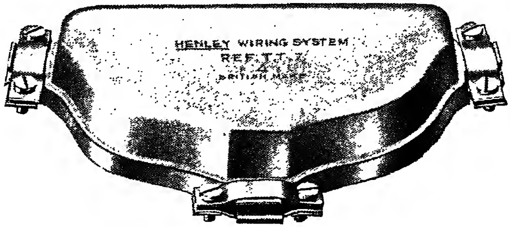


FIG. 32.—Henley tee-box showing continuity clamps at ends.

or leaving them. These clamps will be seen in the Tee-box illustration, Fig. 32.

Where a wood block is used for the mounting of a switch, ceiling rose, or any other fitting, the bonding together of the lead sheathing of the several conductors is effected by means of a circular bonding clamp, as illustrated in Fig. 33. This clamp consists of two tinned brass rings held together by a screw at four points, the conductors being passed through two or more of

the four spaces thus provided. In Fig. 33 two only of these spaces are shown in use. This clamp is, of course, contained behind the wood block, which is recessed out to receive it. To bond the sheathings of the conductors as they enter or leave an ordinary wood cased distribution board, a straight bonding strip is used, as illustrated in Fig. 34. Where Ironclad Distribution Boards or Switches, etc., are used, it becomes necessary to make a watertight joint between the iron and the lead sheathing of the conductor, as well as to ensure good metallic and electrical continuity between them. Figs. 35 and 36 show two designs of fittings which are used. Fig. 35 (Henley & Co.) shows a brass

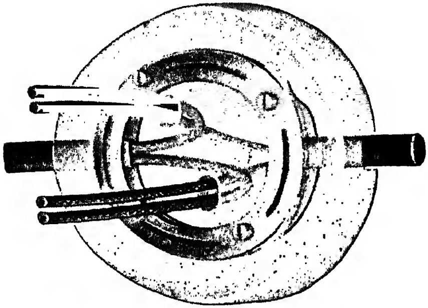


FIG. 33.—Henley universal bonding clamp.

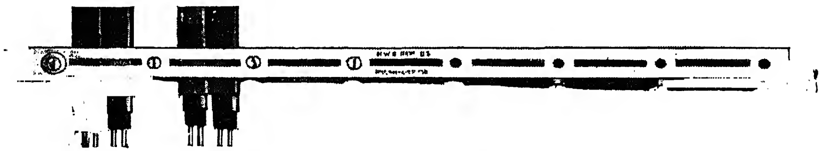


FIG. 34.—Henley bonding strip.

union, and a gland through which the conductor is passed, its lead sheathing being soldered to the latter at the point of entry. Fig. 36 (Walsall Hardware Manufacturing Co.) shows another design, in which soldering is not required, but which is not

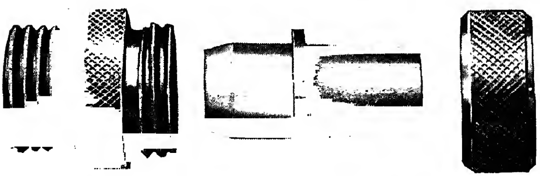


FIG. 35.—Brass union for watertight junction.

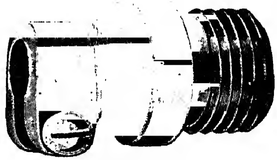


FIG. 36.—Walsall union.

watertight. With either design, the iron case or box is drilled and tapped to receive the screwed end of the fitting.

The Bonding Wire System.—In this system the V.I.R. conductors employed are fitted with a tinned copper bonding wire placed immediately under the lead sheathing, and therefore in electrical contact with it. This enables the wiring system to be carried out without the use of the various clamps, which are otherwise necessary. Figs. 37 and 38 show respectively one of the twin conductors with its bonding wire, and a Tee-box specially designed for this system by Messrs. W. T. Henley. In this latter, a central brass pillar is fitted, on which are a nut and washer for joining the bonding wires. The current carrying conductors are, of course, joined by the usual china connectors.

FIG. 37.—Twin lead-covered conductor with bonding wire. (Henley.)

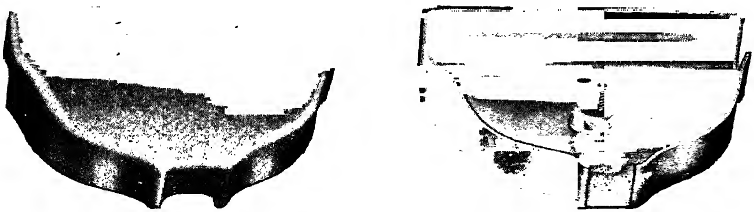


FIG. 38.—Tee-box for use with a bonding wire system.

The 'Kaleeco' Wiring System.—In this system the conductors consist of high conductivity tinned copper wires, insulated with two layers of vulcanised india-rubber, taped and sheathed with a tube of special lead alloy. It will be noted that the usual layer of pure rubber next the wires is omitted. The conductors are described by the makers as of Non-Association 600 megohm class, and are either single, twin or three-core. The method of fixing, although similar to that employed by Messrs. Henley or other manufacturers, includes a rather different pattern of clip, as illustrated in Fig. 39. In this illustration is seen the five separate manipulations of the clip, all of which may be performed without the use of pliers or other tool, and yet result in a very strong and reliable fixing.

Jointing and Bonding.—Jointing is provided by means of the usual china connectors, contained either in a rectangular Tee-box, or a special brass cover, or behind a wood ceiling block. The first two are shown in Figs. 40 and 41. In either case, the metal covers are slotted to receive the conductors by means of a special slotting tool. The method of bonding in this system is quite unique. Figs. 42 and 43 show the three essential parts and their method of use. *A* is a backplate of tinned brass on which the connections are made; *B* is a bonding ring of tinned copper strip; *C* is the *underside* view of a tinned steel bridge ring, showing the brass mushroom tailed bonding screws, and also the bayonet slots, which provide for easy adjustment when assembling. The copper bonding ring is first dropped over the four supporting pillars of the backplate, as in Fig. 44, the bridge ring, *C*, is then reversed, as shown in this figure, dropped over the four pillars adjusted for position by means of the bayonet slots, the mushroom tailed bonding screws tightened up when a good rigid continuity bond is formed, and the conductors firmly held in position. Any make, width or thickness of lead-covered conductor can be used, and it can be brought into the fitting at any position, or from any direction.

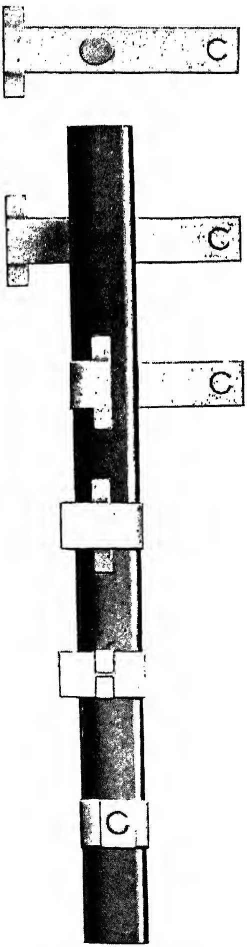


FIG. 39.—Kaleeco clip showing the various operations.

Where it is required to bond the sheathings of the conductors as they enter or leave a wood-cased distribution board, continuity bars of the design shown in Fig. 45 are adopted. It will be noted from the illustration that various sizes of conductor may be equally effectively bonded together.

Special Fixing Saddles.—Where there is a possibility of

electrolytic action being set up between the sheathing of the conductor and its fixing clip, special saddles are used, which are

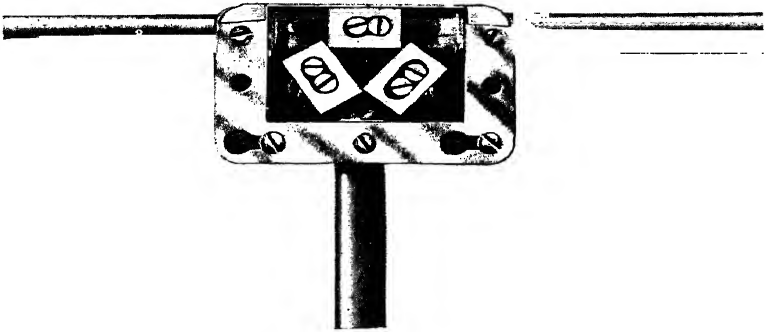


FIG. 40.—Tee-box with cover removed.

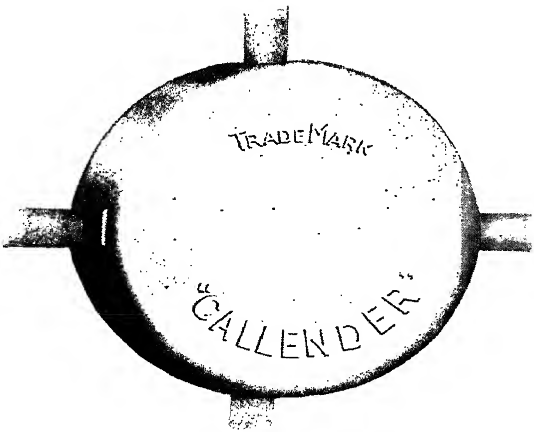


FIG. 41.—Special brass cover containing connectors, etc.

made of the same metal as the sheathing. These are obtainable in all sizes, or they can be made up on the job from the metal strip.

Watertight Junction Boxes.—Where necessary to make a watertight joint, the standard Kalecco junction box is used. A tinned brass collar is fitted inside the bridge ring, to form an inner chamber, which is filled up with 'kalaloid' compound. A final disc of kalaloid is then pressed in on top, thus sealing the chamber.

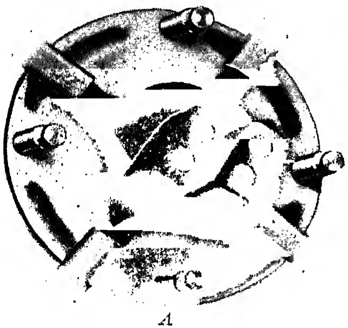


FIG. 42.—Backplate, *A*.

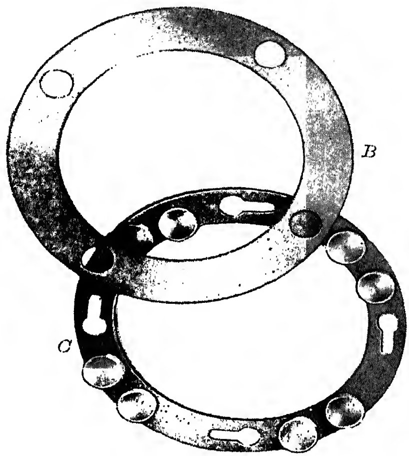


FIG. 43.—Bonding ring, *B*, bridge ring, *C*.

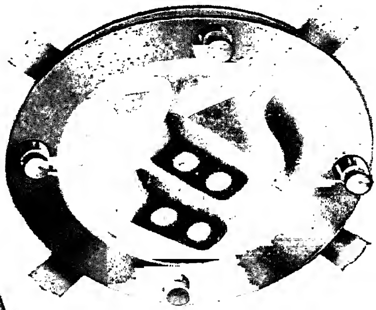
Other Lead-cased Wiring Systems.—Of the many other lead-cased wiring systems in use the following may be mentioned:—

The	'Magnet'	Systems	of the	General Electric Company, Limited.
,,	'Helsby'	,,	,,	British Insulated Cables, Limited.
,,	'Prescot'	System	,,	,, ,, ,, ,,
,,	'J and P'	,,	,,	Johnson & Phillips, Limited.
,,	'Glo-clad'	,,	,,	W. T. Glover & Company Limited.

Generally, all these systems which employ lead-covered conductors differ from one another mainly in the details of the accessories used. Of the three systems of the General Electric Company one employs lead-covered conductors with bonding wire whereas in the second system this is omitted, the usual bonding accessories being therefore required. A third system of the General Electric Company's employs watertight fittings and

accessories, a special feature of which is the patent gland which enables the various lead-covered conductors to be used with iron-clad switches and fuses, etc.

The 'Helsby' systems of the British Insulated Cables, Limited, comprise the ordinary twin lead-covered system, the same with the use of a bonding wire in the conductors, and a watertight



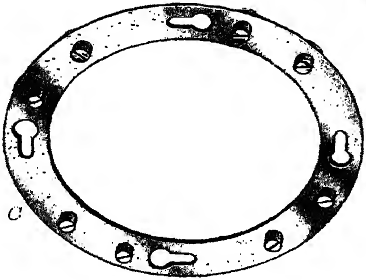


FIG. 44.—Bonding ring and bridge ring, *C*. This reversed ready for fitting.

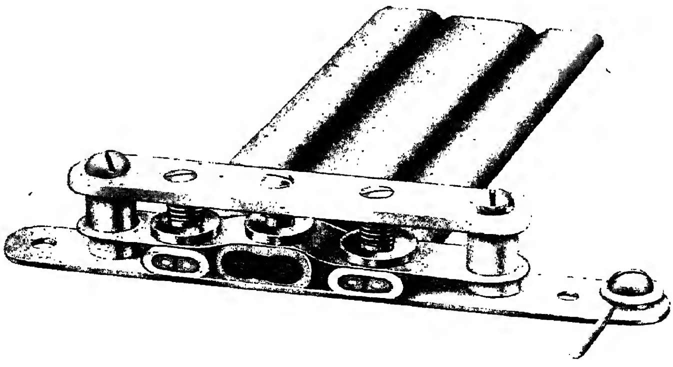


FIG. 45.—Kaleeco continuity bars.

system with special glands. In the 'Prescot' system of this firm the conductors are twin, but insulated with impregnated paper, and lead covered. Paper, being of a hygroscopic nature it is necessary whenever the conductor is likely to be exposed to

moisture to seal the points where the lead is removed, as for example at ceiling roses, switches, junction boxes, etc., hence provision is made in the fittings so that they may be filled with a compound so as to exclude either moisture or air. The glands of all boxes are arranged to firmly grip the cable so as to ensure good electrical continuity throughout. In the Johnson and Phillips system the usual single, twin and three-core lead-covered conductors are employed but without any bonding wire. The bonding clips and other accessories differ a good deal from those of the other systems mentioned, but are of very effective design. Watertight boxes are used where necessary, the gland being packed with fine lead wool.

Glover's 'Glo-clad' system is materially different from any other lead-covered wiring system. The conductors are either twin or three-core, insulated with pure and with vulcanised rubber, the cores twisted, wormed circular and then sheathed with a comparatively heavy lead sheathing, which sheathing is itself *screwed* on the outside, so that when used with an internally screwed brass gland it forms an absolutely watertight connection —and, of course, a perfect bond.

A special tool is employed for cutting the thread on the lead sheathing.

All junction boxes, distribution boxes, switch boxes, etc., are provided with glands into which the cable is screwed.

The system has been designed specially for industrial buildings where severe conditions of service are to be met with.

Points to be Noted in a Lead-covered Wiring System.— *Care in Handling.*—Special care is necessary in the handling of the conductor. It should always be delivered to the site on a drum or reel, and when being taken off same it should not be allowed to sag, and so form very sharp bends, nor should it be allowed to lay or trail upon the ground. Where required to pass through floors, or where otherwise exposed to possible mechanical injury, some protection should be given to the lead sheathing of the conductors, as, for example, by passing them through a length of steel conduit. Where passing through party walls or fire-resisting floors, the piece of conduit containing the lead-covered conductor must be plugged with some fire-proof material so that no space is left through which fire could pass.

Bending the Conductor.—This must be done carefully, and

without haste. By working the conductor round the ball of the thumb, a twin or triple core of the Henley or similar pattern can be bent to a curve of almost any radius, either edgewise or widthwise, without crushing in the lead sheathing on the inside of the curve. Sharp bends, should, however be avoided wherever possible.

Removing the Lead Sheath.—In removing the lead sheath from the conductor, it should be *partially* cut through with a knife. On bending the piece backwards and forwards once or twice, it will break away from the main piece, and it can then be withdrawn. Many faults may be caused by cutting the lead sheath right through its thickness.

Removing the Tape.—In removing the tape from the vulcanised rubber, for the purpose of making a connection, at least equal care must be exercised as with ordinary V.I.R. conductors, that is to say, the rubber must not be nicked or pared, and no stray threads from the tape be left protruding.

Earthing.—The lead sheathing of the conductors, in addition to being made electrically continuous throughout, must likewise be earthed, as would be done in the case of steel conduit. Likewise, the total resistance, as measured between a point near to the main switch and any part of the installation, must not exceed 2 ohms.

THE 'STANNOS' SYSTEM.

In this system, the conductors used are insulated with both pure and vulcanised india-rubber, and two layers of paper tape, over which is a closely compressed sheath of tinned copper. This latter serves as a mechanical protection or armouring wherever Stannos conductors are used for an ordinary two-wire system of wiring. They are, however, sometimes used to form a 'concentric' system of wiring, in which case the tinned copper sheath is made to serve as the uninsulated, earthed return conductor. A cross-section of a Stannos 7 / ·064 conductor is shown in Fig. 46.

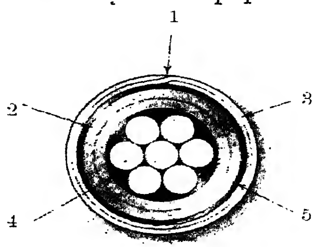


FIG. 46.—Cross-section of Stannos conductor.

1. Solid sweated joint and sheath. 2. Vulcanised rubber. 3. Tinned copper sheath. 4. Pure rubber. 5. Paper tape.

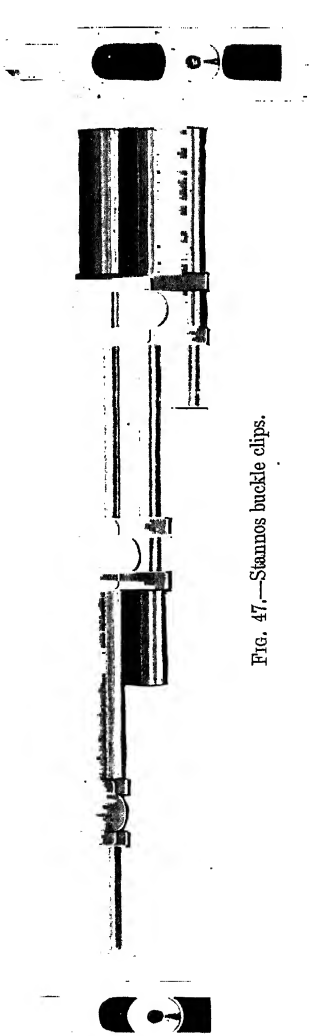


FIG. 47.—Stannos buckle clips.

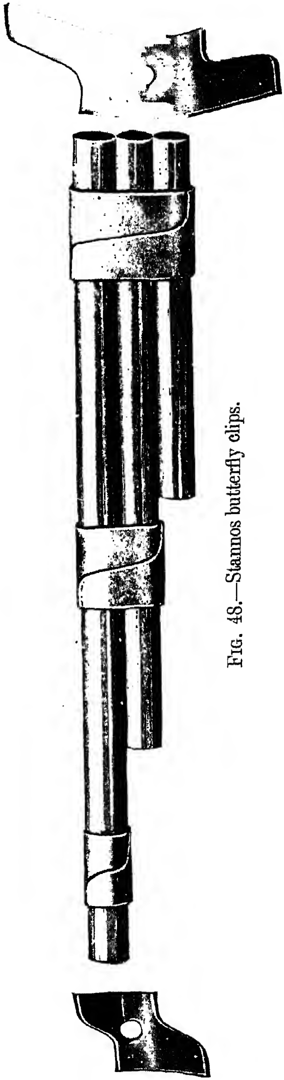


FIG. 48.—Stannos butterfly clips.

Method of Fixing.—The conductors are attached to the surface of the wall or ceiling by tinned clips, mostly of the 'buckle' pattern, as shown in Fig. 47. The clips are first fixed in position by screws or nails, the conductors are then laid over them, and the clips bent over, the tongued end being passed through the hole at the other end, and finally bent sharply over.

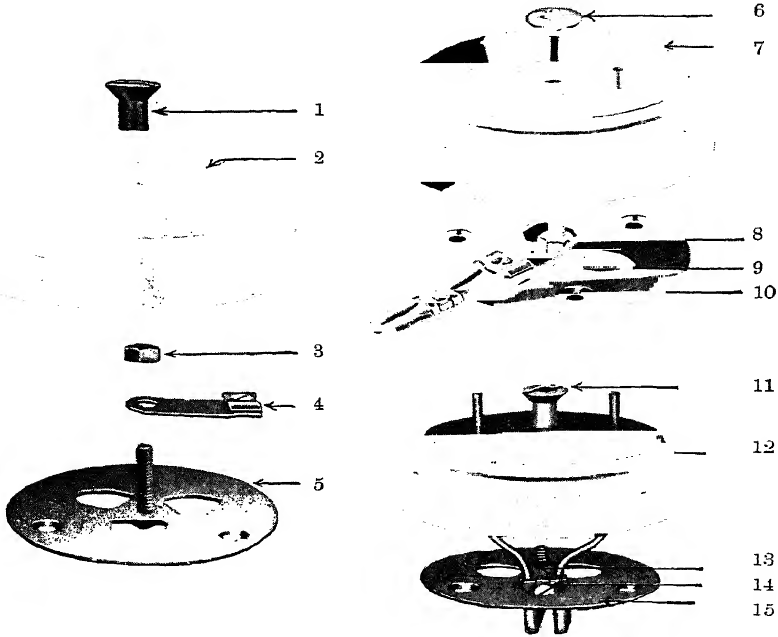


FIG. 49.—Stannos backplate clamp and screws, etc., used for bonding.

1. Countersunk head.
2. Wood block.
3. Hexagon nut.
4. Side entry screw clamp.
5. Backplate.
6. Countersunk head.
7. Wood block.
8. Hexagon nut.
9. Side entry screw clamp.
10. Backplate.
11. Countersunk head.
12. Wood block.
13. Hexagon nut.
14. Back entry screw clamp.
15. Backplate.

Another pattern is the 'butterfly' clip, an illustration of which is given in Fig. 48. This is made of heavier metal, and therefore more suited to rough positions. It is fixed by nails or screws in

the ordinary way. The two tongues are bent over the conductors by hand, and finished off with a *light* hammer.

Jointing and Bonding.—As in other metal-cased wiring systems, jointing must be performed by means of connectors, these being contained within the recess at the back of the wood block. For bonding the sheathings of the conductors, a tinned brass continuity backplate is used, this also being fixed behind the block, one such backplate being provided at all outlet points, whether for a switch, plug, or light. The connection between the conductor sheathing and the backplate is formed by means of a tinned screw clamp which is secured to the plate by a small hexagon nut. In Fig. 49 will be seen the several parts referred to separated out, and also assembled together, ready for fixing.

Bonding strips at fuse-boards, etc., and earthing clips for the main conductors are, of course, necessary in this system. Fig. 50

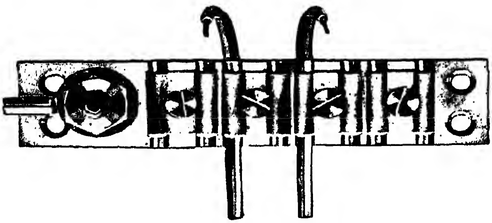


FIG. 50.—Stannos bonding strip for fixing at a fuse-board.

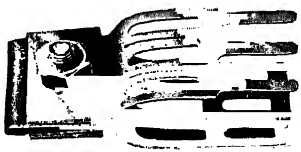


FIG. 51.—Stannos earthing clip.

shows a view of one of the former, and Fig. 51 a Stannos earthing clamp for a water-main. This, it will be noticed, is an adaptation of the Stannos 'Buckle' clip.

The points which have already been given as being necessary to observe for properly installing a *lead*-covered wire system, apply equally well where the conductors used are of the 'Stannos' pattern.

CHAPTER VI.

NON-METAL CASED WIRING SYSTEMS.

The Helsby Ebonite Wiring System.

The principle of this system is that the conductors as well as their connections, the fuse-boards, switches, ceiling roses, etc., are all completely enclosed in ebonite. This material being unaffected by chemicals, the system is intended for use in such places as chemical works, dye works, bleach works, etc., where any system employed must be corrosion-proof as well as fume-tight and water-tight. The ebonite sheathed conductors are of V.I.R. insulation, 600 megohm grade, C.M.A. They are either single, twin or three-core, and are made up to a uniform overall diameter of half an inch, so that generally only one size of gland becomes necessary for the various fittings. The coils of cable as sent out are about 3 feet 6 inches diameter, and before they can be uncoiled it is necessary to apply heat. This may be done by immersing the coil in hot water for a few minutes or the conductor may be loosely wrapped with some sort of fabric soaked in water and then heated with a blow lamp. As soon as the sheathing becomes soft enough the conductor is straightened out to the requisite length, and on cooling the sheathing becomes hard again so that it retains the shape given to it. To cut the cable it is only necessary to make a slight incision in the ebonite by means of a pocket-knife, when on giving it a sharp bend it will crack and may then be readily drawn off.

The 'C.T.S.' System.

The C.T.S. (or cab-tyre sheathed) system differs from all other systems of wiring in the fact that no metallic armouring is provided for the conductors, nor are they intended to be enclosed in steel conduit or other form of mechanical protection. They consist of high conductivity tinned copper wires insulated with pure and with vulcanised rubber, and then sheathed overall with a layer of specially tough rubber compound, known as 'Cab-Tyre Sheathing.'

It will be noted that no tape or braiding enters into the composition of the conductors. The insulation is either the 600 or the 2 500 megohm grade, C.M.A.

The C.T.S. conductors are made up either as singles, flat twin, round twin, or as round three-core cables.

Fixing and Fittings.—The conductors are attached to the surface of the wall or ceiling, by lead clips or saddles, which are cut up on the job, from ordinary lead strip about $\frac{3}{8}$-inch wide and

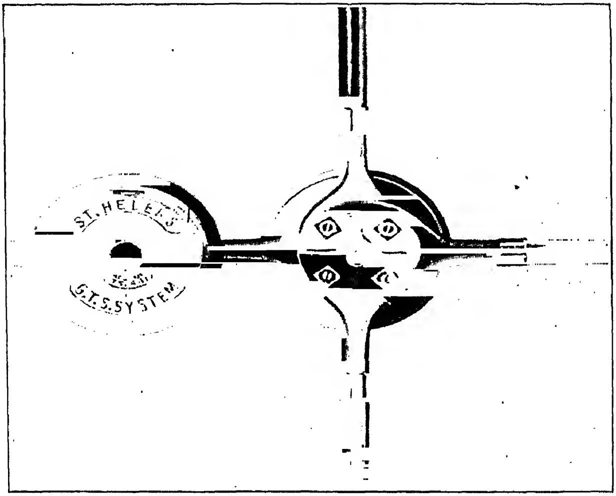


FIG. 52.—C.T.S. connector box.

$\frac{1}{16}$-inch thick. Ordinary fittings are quite suitable for use with the C.T.S. system.

Joints in the conductors are best made in a connector box such as that supplied by the originators of the system, The St. Helen's Cable Co., Ltd. An illustration of one of these boxes is given in Fig. 52. Ordinary china connectors are used for making the joints, these being accommodated on the base of the box which is made of moulded insulation. The cover, which is made of the same material, is fixed in position by means of a single thumb-screw. For use in damp or corrosive situations, special watertight connector boxes are used.

As a system, C.T.S. is obviously a cheap one. The conductors are waterproof, will withstand rough usage, do not kink, and are said not to be affected by acids or alkalis.

The Cleat System.

In the 'Cleat System' of wiring, which, in the earliest days was the first system to be used, the ordinary V.I.R. insulated con-

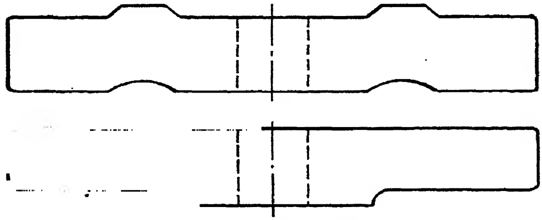


Fig. 53.—Two-groove double cleat.

ductors are laid along the surface of the wall or ceiling, and fixed in position by means of double cleats. These latter are made of glazed porcelain, and therefore serve also as good insulators. Only the double pattern is now used, and these serve, therefore, not only to isolate the conductors from one another, but also from contact with the wall or ceiling, thus providing a free circulation of air all around them. An illustration of a two-groove double cleat is shown in Fig. 53.

With this system, any class of V.I.R. insulated conductors may be used, provided they are taped and braided; and any ordinary fittings. A fitting which is particularly useful for this system of wiring is the 'cleat' pattern ceiling rose, manufactured by the British Thomson Houston Co. A view of this fitting is shown in Fig. 54, from which it will be noted that the square china base is provided with two grooves on either side for receiving the incoming or outgoing wires. Another feature of this rose is the top or cover on to which the flexible cord is wired, a half

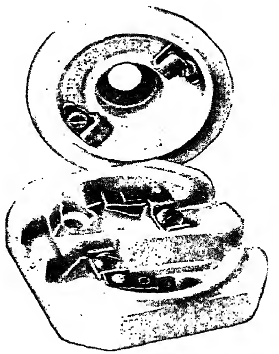


Fig. 54.—Cleat ceiling rose, by B.T.H. Company.

turn of this sufficing to firmly engage it with the contacts, which are fixed on the base, for receiving the circuit wires.

Points to be Noted in a Cleat-wiring System.—(*a*) Where the conductors come within 6 feet of the floor, or where they might otherwise be liable to mechanical damage, they should be protected by being enclosed in wood casing or steel conduit. This point obviously applies to switch drops.

(*b*) The conductors should always be in view throughout their length, and therefore may not be placed under floors, or behind partitions, etc.

(*c*) They must be kept well clear of all gas or water-pipes, and should be run above in preference to below, the same.

(*d*) Where passing through walls, floors, partitions, etc., they must be enclosed in some form of fire-proof tube, the ends of which must be plugged with similar material.

The Cleat system of wiring has many uses. Given a dry situation, free from corrosive fumes, it becomes very suitable for railway stations, goods sheds, many factory jobs, and all sorts of temporary wiring. During the war it had many applications, not only in factories, but in temporary office buildings, where it was necessary that cheapness in first cost, combined with safety, should obtain.

Wood Casing.

This system of wiring has, during the last few years, been practically superseded by the conduit and metal-cased wire systems. A section of a piece of ordinary two-groove casing, with its capping (or cover) attached, is shown in Fig. 55. The capping is fixed by screws, sizes over 2 inches in width being screwed at the sides, instead of along the centre only. It is desirable to run conductors of opposite polarity in separate grooves. Where a conductor is required to cross over another, which is not of the same polarity, the separation is provided either by a short 'bridge' of casing, which is fixed over the other, or by the insertion of a short strip of mica at the point of crossing.

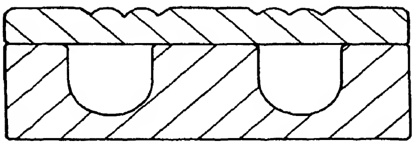


Fig. 55.—A section of two-groove wood casing.

Wood casing suffers from the disadvantages of being neither fire nor damp-proof, and is not suitable for sinking under plaster work.

CHAPTER VII.

WIRING OF SPECIAL POSITIONS.

WHERE the position to be wired is an ordinary one, and therefore does not present any special condition such as dampness, moisture, excessive temperature, etc., the choice of a system of wiring is a fairly simple matter. For instance, in such cases as a private residence, office blocks, shop, hotels, etc., one of the several conduit or metal-cased wire systems are commonly chosen. Unfortunately, in many instances, a low first cost is the one factor considered; efficiency, fire risk, or low maintenance costs being left out of consideration altogether.

Certain places and positions will, however, always require special treatment, if lasting efficiency is to be obtained.

Conservatories, Palm Houses, etc.—In these positions, wide variations of temperature occur which, with a naturally moist atmosphere, invite condensation. For this reason, a conduit system of wiring, with ordinary V.I.R. conductors, is liable to suffer by way of insulation breakdown, whenever and wherever condensation occurs. To meet this case, either the C.T.S., or a lead-covered wiring system, would be appropriate, provided always that watertight accessories and fittings be used, as necessary, and that mechanical protection to the conductors is adopted where they might otherwise suffer injury. Another method, which has proved very successful is to use V.I.R. lead-covered conductors, enclosed in ordinary wood casing which has been treated with good oil paint both inside and out. The capping will be securely fixed with round-headed brass screws at the sides, as well as the centre fillet, and after completion of erection, receive a final coat of paint.

The principle of watertightness must, of course, be maintained

everywhere throughout the installation, whichever of the forego-ing systems be adopted. For this reason, switches and distribution boards will either be located in an adjoining room or place not subjected to temperature variation, or, alternatively, must be made watertight. Lamp-holders will not present any difficulty, as they will either be contained (with their lamps) in watertight fittings, or may themselves be made watertight by being carefully taped up. If wood blocks be used for the mounting of switches or fittings, etc., these can also be made watertight by the recess at the back being filled in solid with compound.

Outdoor Positions.—The wiring to positions which are on the outside of the wall of a building, is, wherever possible, run *inside* the building, a hole being made in the wall through which the conductors are passed to the bracket, lantern, or whatever fitting is used. Cases, however, frequently arise, where the position to be served is away from the building, and the conductors have to be taken thereto, underground. The system then usually adopted is that of V.I.R. conductors drawn into heavy gauge, screwed wrought-iron pipe, preferably galvanised inside and out. Ordinary conduit is unsuitable, as being of too light a section. The V.I.R. conductors should preferably be of the lead-covered class.

Trench and Pipe Line.—The trench, if under ordinary footpaths, should be not less than 18 inches deep. For carriage-ways, the depth must be increased according to the class of traffic likely to pass over. The bottom of the trench must be well consolidated by ramming, before the pipe-line is laid in position. This pipe-line should be carefully levelled, and provided with means of drainage at its lowest point, for which purpose a Tee-piece is commonly used, the leg of the Tee looking downwards into some loose stones, etc. Where two or more underground pipe-lines join up with one another, the use of a junction box becomes necessary. These junction boxes should be of heavy section, to resist deterioration, and be finally filled in solid with 'box-filling compound.' As the compound is about to solidify, the lid of the box will be placed on and well screwed down, so as to complete a thoroughly watertight job.

Underground pipe-work must be positively earthed, as would be done with interior conduit, and likewise the lead sheath-ing, if any, of the conductors contained in it.

Underground Mains and Sub-mains.—These have frequently to be laid between the engine house, on a country estate, and the mansion, or between one factory building and another. In these, and similar cases, the sizes of the conductors are usually appreciable. The point then arises that it is cheaper to use a concentric, paper insulated, lead-covered and armoured conductor than the corresponding section in V.I.R.

FIG. 56. — Henley joint box, vertical pattern.

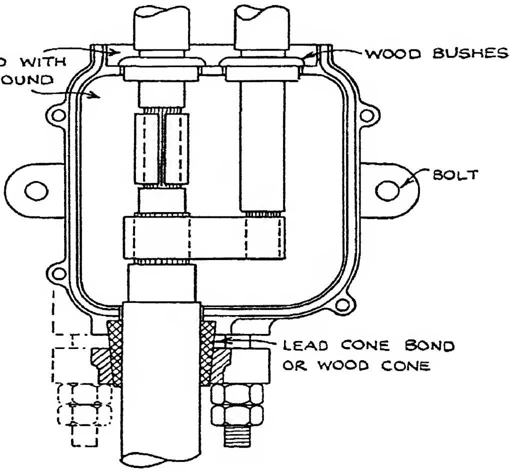


FIG. 57.—Section of Henley joint box.

One of the following methods of laying will then be adopted :—

(1) The conductor laid *direct* in the ground, without further protection, in which case it will probably be lead covered, with a jute serving, double steel tape armoured, double jute served, and finally compounded with a waterproofing compound.

(2) An alternative method is to lay the cable on the 'solid' system. A trough is made up of rough-sawn timber, the bottom being nailed to the sides. Having been placed in position in the trench, a layer of molten bitumen is run in and allowed to set. The cable is then laid in, and the trough filled up solid with bitumen, and whilst this is still semi-plastic, a lid or cover of rouge-sawn wood is laid over, this preferably being rather wider than the trough. This system is both cheap to instal and very

efficient. Care in running in the bitumen is, of course, necessary, in order to ensure that no vacuities are formed. As these paper insulated cables have to be connected to apparatus of some kind at either end, it is usual to provide a joint box for the purpose of housing the joints between the concentric conductor which enters it at one end, and the two V.I.R. conductors or 'tails' which will pass out at the other. An illustration of one of these joint boxes of the vertical pattern is shown in Fig. 56 and a section of the same in Fig. 57. In this latter will be noted the split lead cone and the clamping device for bonding the lead sheathing of the concentric cable to the iron box, so as to obviate the use of a wiped joint.

Wherever a change of direction occurs in the run of an armoured cable, whether above or below ground, it must not be bent sharply. The radius of the bend should not be less than six times the overall diameter of the cable.

Battery Rooms.—Although only a few lighting points are necessary in a battery room, special care must be taken with the wiring if efficiency and safety are to be maintained. Owing to the corrosive action of the sulphuric acid vapour, which is always present, the most reliable system will be a screwed conduit one. The conduit must be kept well away from the walls by spacing saddles, so that it does not help to retain acid moisture in contact with it. The most suitable fittings will be those of the cast-iron well-glass pattern, thoroughly gas and watertight. Any switches or plugs in the room will likewise be contained in cast-iron watertight boxes, into which the conduit is screwed direct. The conduit, and all other metal-work, must receive at least two coats of 'anti-sulphuric' enamel, to preserve it from deterioration.

Stables, Cowsheds, etc.—In these positions, two possibilities have to be considered: (*a*) mechanical damage to the wiring, and (*b*), its possible deterioration by chemical action, due to the vitiation of the atmosphere by animal refuse. To meet the first point, the wiring work, switches, etc., must be kept well up out of the reach of the animals, otherwise damage invariably results.

The system of wiring chosen must be such as will not be affected by the corrosive atmosphere present, and to meet this point, screwed steel conduit work will doubtless give the best results.

Light fittings will be of the cast-iron well-glass or bulkhead

type, and switches and plugs enclosed in cast-iron boxes. All fittings, as well as the conduit, should be well treated with oil paint.

Public Lavatories and Conveniencies, etc.—These positions require similar treatment to stables, as regards the fittings and switches employed. Lead-covered wiring, if kept well painted, appears to stand up well, as would, of course, screwed conduit. In view of the great condensation on wall surfaces, conduit work should be kept off the surface by the use of spacing saddles.

In the ordinary lavatories attached to office blocks, or other private or public buildings, trouble with the electrical installation is not infrequent. Experience proves this to be due to: (*a*) unsuitable fittings, particularly switches; (*b*) carelessness in the wiring work, especially in the connecting up of switches or other fittings; (*c*) the omission of proper earthing of external metal-work. In every case, such causes of trouble can be avoided, and the installation rendered as reliable as in any other position.

Garages.—The electrical installation in a garage requires to be made as fireproof as possible. To this end it is desirable that a screwed conduit system of wiring should be adopted and care be taken that no open ends of conduit anywhere occur. Any conduit boxes or inspection fittings required will be of the watertight pattern with machined faces. Should a garage be of sufficient size to require its own distribution board, this would best be of an iron-clad pattern and for further security would be fixed external to the room. The lighting fittings used should be of the iron-clad 'well-glass' type and both watertight and gastight. Switches and plugs must in each case be fixed not less than 6 feet above the floor and should be contained in watertight and gastight iron boxes.

Churches.—It is sometimes urged that a metal-cased wire system must, essentially, be the best for churches, owing to the alleged difficulties of: (1) concealing any conduit work from view, and (2) bending or setting it, so as to fit neatly and closely the principal features of the architecture. Where, however, proper skill is exercised in selecting positions for the runs, and generally in carrying out the work, neither of these difficulties appear. It is imperative that, in a church, every precaution should be taken to avoid any risk of fire. The main runs will generally be either in the roof, or beneath the church floor, each of which are usually of

timber construction. Any electrical work at the organ, whether for lighting, power, or heating, is, likewise, surrounded by woodwork. These, and other points, call for careful consideration where safety is concerned. If metal-cased wiring be used, it should not be laid direct on rough brickwork, owing to the possibility of mechanical injury to its sheathing. In contact with oak, lead-covered wire is liable to deterioration. Many considerations, therefore, would tend to the selection of a screwed conduit system as the most desirable.

'Aerial' or Insulator Wiring.—This class of wiring work is applied particularly to such outdoor positions as docks, harbours, piers, etc., also in factories, railway stations, goods sheds, exhibitions, etc. The conductors for this class of work are already

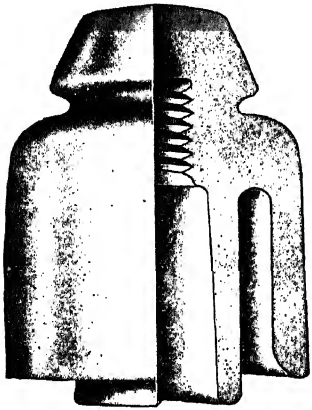


FIG. 58.—Pole insulator. (British Insulated Cables, Limited.)

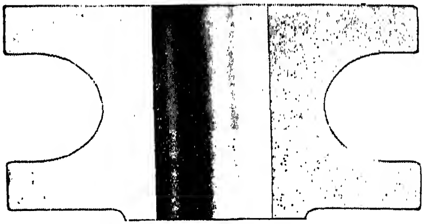


FIG. 59.—Reel insulator.

described in the chapter devoted specially to that subject. The insulators mostly used are the two patterns shown in Figs. 58 and 59. The former is the ordinary 'petticoat' insulator, and the latter the 'reel' or bobbin type, as sometimes selected for work on wall surfaces. These insulators should be made of well-glazed English porcelain, the bolts or stems which carry them being screwed rather than cemented in. Insulators of a fairly good size are always to be preferred to small ones, which do not, of course, offer so good a resistance to surface leakage.

For securing the conductors to the insulators, tinned copper binding wire is usually employed, 18 S.W.G. being the smallest size which should be used for this purpose.

Where the conductors are required to pass through the wall of a building, glazed porcelain or earthenware leading-in tubes, having

bell-mouthed ends, are used, these being rigidly fixed in the wall with Portland cement.

Where the aerial conductor is required to be passed into the terminal of a switch, fuse, etc., special care is necessary. Being of hard-drawn copper, it is difficult to bend. The end to be inserted into the fitting should, after stripping and cleaning, be well-tinned. This will have the effect of annealing it, so that the strands may readily be twisted up with pliers, and the end bent into the required position.

Wiring work with any form of aerial conductor must be kept well out of the reach of unauthorised persons, and where this is not permissible, it should be cased over.

In aerial wiring, it often becomes necessary, owing to the lengths of run being considerable, to make joints in the conductors. If the conductors be stranded, the jointing will be done

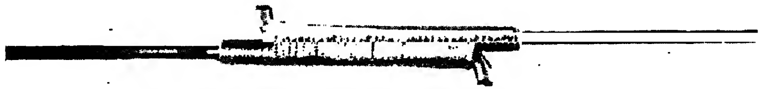


FIG. 60.—Britannia joint.

in the usual way, the hard-drawn wires being first annealed, by tinning the ends of the strands. Should it be necessary to joint a solid, bare conductor, such, for instance, as a No. 8 S.W.G., it is best to employ a Britannia joint. Inasmuch as modern wiremen are not always accustomed to this, an illustration of such a joint is shown in Fig. 60.

The method of making the joint is as follows: The two ends of the wire, to the extent of three to four inches, having been well tinned, the tips will be slightly upturned; the two wires will then be tacked together with solder, lapped the whole length of the joint with tinned copper binding wire, and finally soldered right through.

Overhead Constructional Work.—In this country wood poles are mostly used for carrying the overhead conductors, where this method of construction has to be employed; the timber preferred for the purpose being either red fir or larch. They should be well creosoted under pressure, to resist decay.

The number and size of the poles must, naturally, be governed by the local circumstances of each case.

For fixing the insulators to the poles, it is best to employ wrought-iron clip brackets of the general design, shown in Fig. 61. The practice of screwing a swan-neck bracket direct into the wood pole, in order to effect a slight saving in the first cost, is an evil practice much to be deprecated.

Lightning Arresters.—In many outdoor positions, overhead lines require to be protected from possible lightning discharges. The reason for providing this protection is that the line, if struck, will be the means by which lightning will enter the building where the line terminates. Should this happen, the electrical apparatus contained might be ruined, and the further risk arise

. 61.—Wrought-iron pole bracket.

of fire or damage to the building. One arrester, at least, must be provided for each line, and it will be fixed either on or as near as possible to the building to be protected. The one side of the arrester will be connected direct to the line which is to be protected, and the other direct to a good earth, the length of the earth connection being kept as short as possible.

The simplest form of arrester would be an air-gap interposed between the overhead line and earth. This would allow the high-voltage lighting discharge to pass to earth, but, in all probability, its resistance could not be relied on to prevent an arc being sustained, in which case the line current would follow.

The 'Shaw' non-arcing arrester is illustrated in Fig. 62. This apparatus consists of a series of mica discs (having a number of holes drilled near the circumference) and carbonised rings arranged alternately on a cylinder, this being supported at its ends by toothed metal cups enclosed in porcelain and mounted on

a porcelain base. For mounting outdoors, the whole apparatus is enclosed in a watertight cast-iron box.

Connections.—The conductors used for both line and earth connection should be as short and as straight as possible. Either terminal of the arrester can be connected to the line, the other

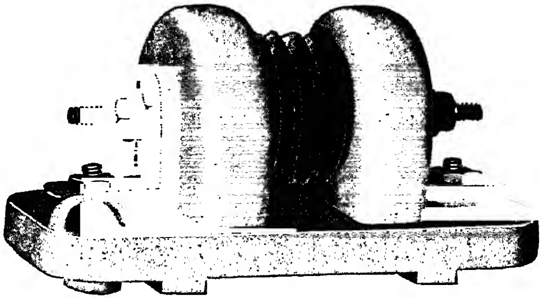


Fig. 62.—The 'Shaw' non-arcing Lightning Arrester.

terminal being connected to earth. The general principles covering earthing, as outlined in the section of this book, dealing with the earthing of conduit, apply also to lightning arresters.

A separate earth connection should be provided for each arrester.

Portable and Temporary Wiring.—For providing the electric lighting or electric power for shipyards, docks, wharves, or riverside premises, it is necessary to have a system of wiring

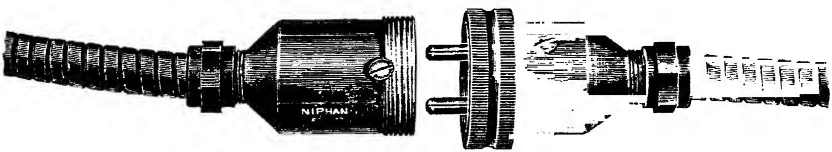


Fig. 63.—The 'Niphan' coupling.

which is extremely robust, always reliable, and which can be moved about from day to day by unskilled labour. It is usual, in the cases mentioned, to have a number of fixed plug-points fed by underground or overhead wiring, and from which current can be taken by flexible conductors to the movable lamps or other appliances.

In the 'Niphan' system, the flexible conductors are usually armoured by being contained in 'flexible steel metallic tubing.'

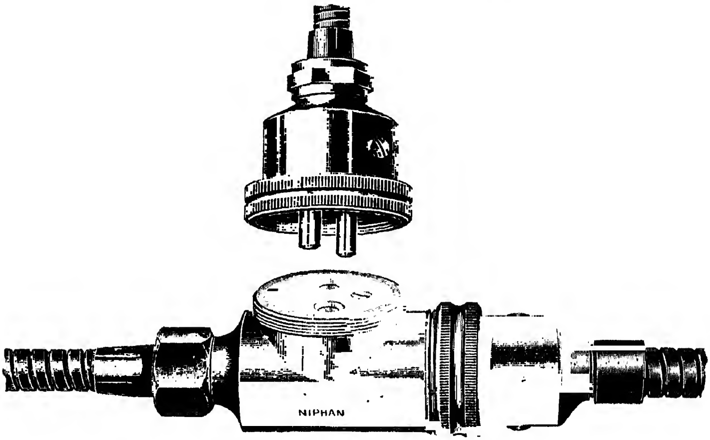


FIG. 64.—'Niphan' tee-coupling.

They are fitted with a special screw coupling at each end, so that any desired length of run can be made up, in much the same way as would be done with several lengths of ordinary firehose. For convenience in operation, it is usual to have a number of different lengths of these armoured flexible conductors, so that points at varying distances from the fixed plug positions may be reached.

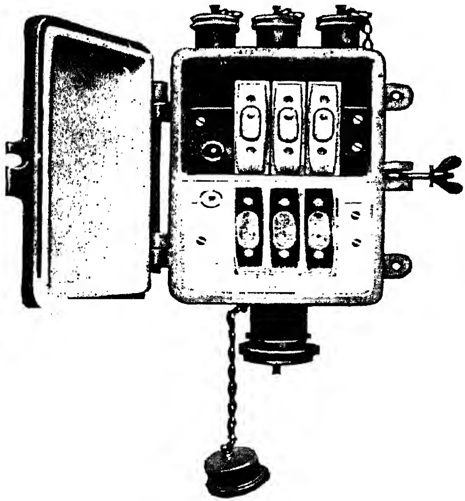


FIG. 65.—A three-way iron-clad distribution board for 'Niphan' wiring system.

Fig. 63 shows one of the special couplings, the two parts being separated, so that the method of screwing together may be more clearly seen. A T-coupling to feed a branch

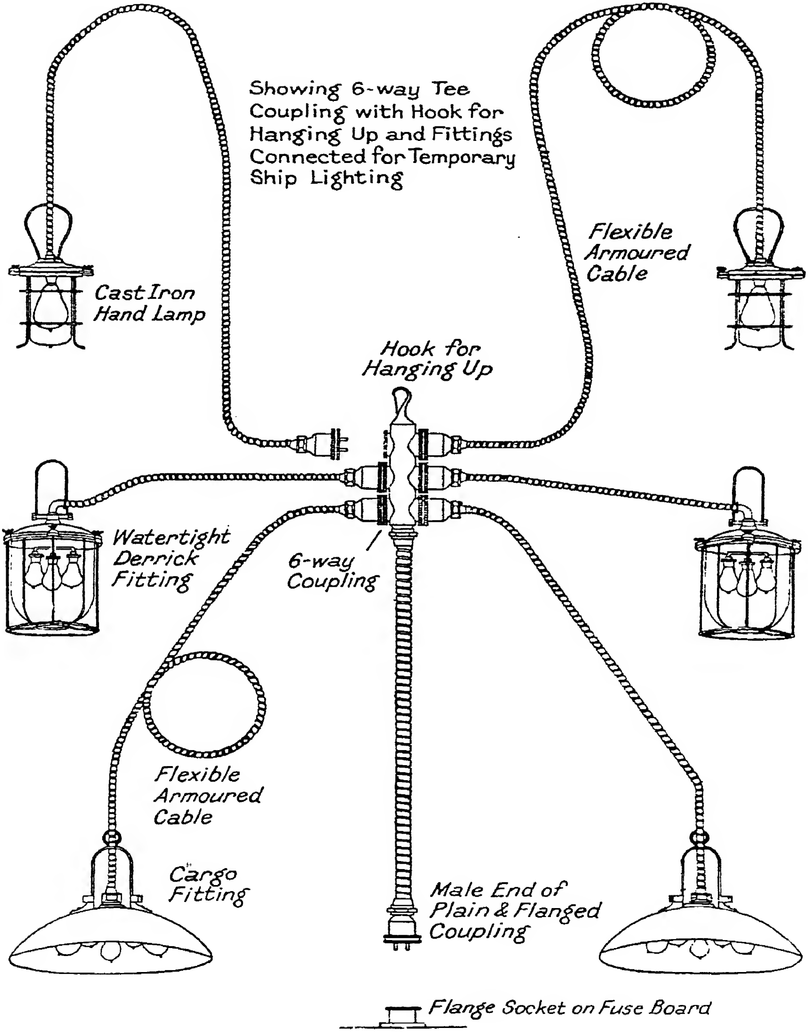


FIG. 66.—Six points fed by portable connections from a multiple-way coupling.

circuit is shown in Fig. 64. The method of securing the flexible metallic tubing to the fitting is a particularly important point, in view of the rough usage which this class of material is bound to receive. For tubes of small size, a brass cone is used, which is sweated direct on to the flexible. For the larger sizes, however, a brass collar is preferred, this being screwed directly on to the tubing.

The same system of screw-on plug connections is applied to Iron-clad Distribution Boards, a three-way pattern of one of these being shown in Fig. 65. The sockets at the top are for connection to the circuits, and the socket at the bottom for the incoming mains. When not in use, the couplings or sockets are kept sealed by a screw-on cap, as shown in the last illustration. Fig. 66 shows, in a diagram form, how six separate positions would be supplied with current for movable, temporary lighting (or power) with the 'Niphan' system of couplings and flexible armoured conductors.

It should be noted that flexible metallic tubing is sometimes rubber packed. The kind to be used for the armouring of the conductors must be without rubber, that is, 'all metal'—in order to ensure that it shall be sufficiently earthed throughout.

CHAPTER VIII.

CIRCUITS AND THEIR WIRING.

Lamp Connections (Parallel).—The usual method of connecting lamps is in 'Parallel,' as shown in the diagram Fig. 67.

The current from the public or other supply being delivered at a constant pressure, the voltage across the lamps is assumed to be the same throughout, the current, however, being split up between them.

Parallel connection has the following advantages:—

(*a*) The failure of any one lamp does not, in any way, affect the others.

(*b*) The lamps may be either all of the same size (or 'wattage'), or if desired of various sizes. In the former case, the current per

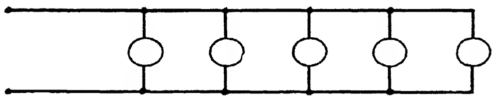


FIG. 67.—Parallel connection of lamps.

lamp will, of course, be equal, and, in the latter, it will vary according to size.

Series.—For special cases, a 'series' connection is sometimes used, as shown in Fig. 68. Here the voltage will be split up round the circuit, but the same current flows through each lamp. Thus, any one lamp failing will open the circuit and put out the lot, unless some special automatic protective device be employed to prevent this. Lamps for connecting in series must, of course, be of the same 'wattage.'

Two-wire Circuits.—In a modern two-wire circuit, the conductors feeding the lamps are arranged to radiate from one or more distributing centres, and in large installations, from the main distributing centre to sub-centres, and from the final sub-centre to

the lamps. In nearly every case, the distributing centre is a 'distribution board' or fuse-board wherein are grouped all the fuses for controlling the several circuits which originate therefrom, a 'fuse' (or 'cut-out') being a piece of readily fusible wire or foil

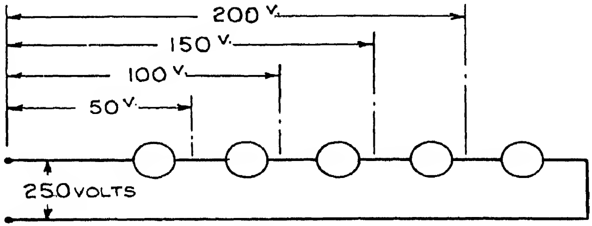


FIG. 68.—Series connection of lamps.

of such size and material that it will melt, and thus open the circuit, should a dangerous excess of current pass through.[1] It is usual to insert a fuse in each 'live' conductor, thus, in a two-wire circuit, each pole is separately protected.

Fig. 69 shows in a diagram form a three-way distribution board, feeding three simple circuits of lamps in parallel, the switches for the lamps being omitted for the sake of clearness. F.F.F. are the fuses, and B.B. are the 'bus' bars, into which current is fed from the source of supply.

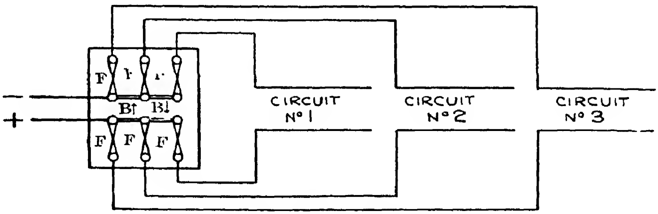


FIG. 69.—A three-way distribution board feeding three circuits.

The following points should be noted as essential to a genuine distribution board method of wiring: (*a*) That each fuse for each circuit is located *at* the distributing centre; (*b*) that only one size of conductor is used for a circuit, so that there is no reduction in the size of conductor, after it has left the distribution board.

[1] Details of fuses and their construction will be found in the section of this book dealing with 'accessories.'

In order that any installation may be adequately controlled and protected, certain apparatus is necessary between the distribution board, as diagramatically illustrated in Fig. 69, and the source of supply. Where the 'service wires' or mains enter the building, they will first be led into the main fuses which are provided and fixed by the supply authority. From this point, one conductor will pass through the meter, and thence to the consumer's own main switch and main fuse. The other conductor, after leaving the supply authority's main fuse, passes direct to the consumer's main switch and main fuse. These connections are shown in Fig. 70. This diagram also serves to illustrate the method of wiring from a main distribution board to several sub-distribution boards feeding lamp circuits. The main distribution board may

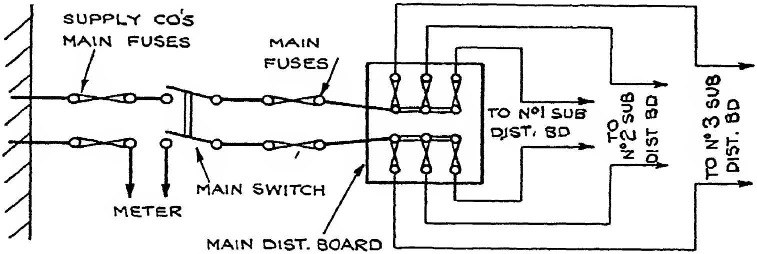


FIG. 70.—Connections for a two-wire service, showing main and sub-main distribution boards.

have fuses only as in the foregoing diagram, or it may also be provided with switches to control the several fuses. The advantage of inserting a switch between the bus-bar connection and the fuse, enables the latter to be made 'dead,' should it, at any time, be so desired. It will be noted that, in either case, each sub-fuse board and the conductors which feed it are protected by fuses, and also that no lamps are connected *directly* to these conductors or feeders.

Another method by which the several distribution boards of an installation may be fed, is illustrated in Fig. 71. In this diagram it will be noted that there is no 'main' distribution board, but that the main conductors or feeders are 'looped' from one distribution board to the next. The object of this method is economy in first cost, but it has the great disadvantage that, should a fault occur on the 'live' side of any one distribution board, the whole

system must be temporarily shut down whilst this is being put right. The better plan where one pair of feeders has to supply each distribution board in turn, is to insert local fuses in these

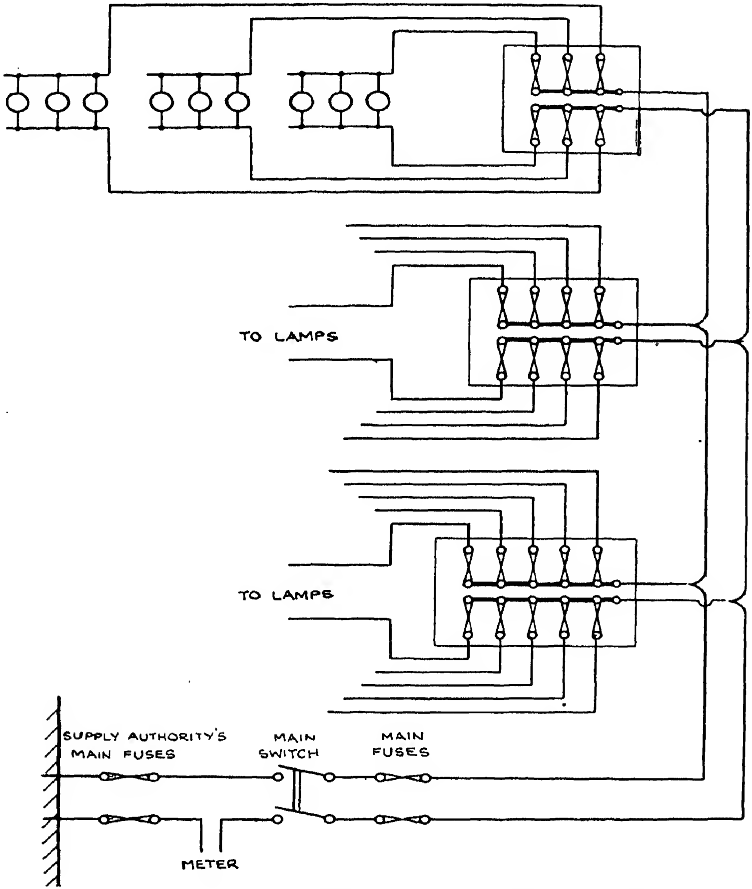


FIG. 71.—One pair of feeders looped from board to board.

feeders as near as possible to each distribution board. The wiring connections would be as shown in Fig. 72.

Distribution Boards and their Circuits.—The number of distribution boards, their positions, their sizes or number of 'ways,'

and the number of circuits to be fed from them must be governed by the nature of the building to be wired, its size, the number of rooms or places, and the purposes for which they are used. The

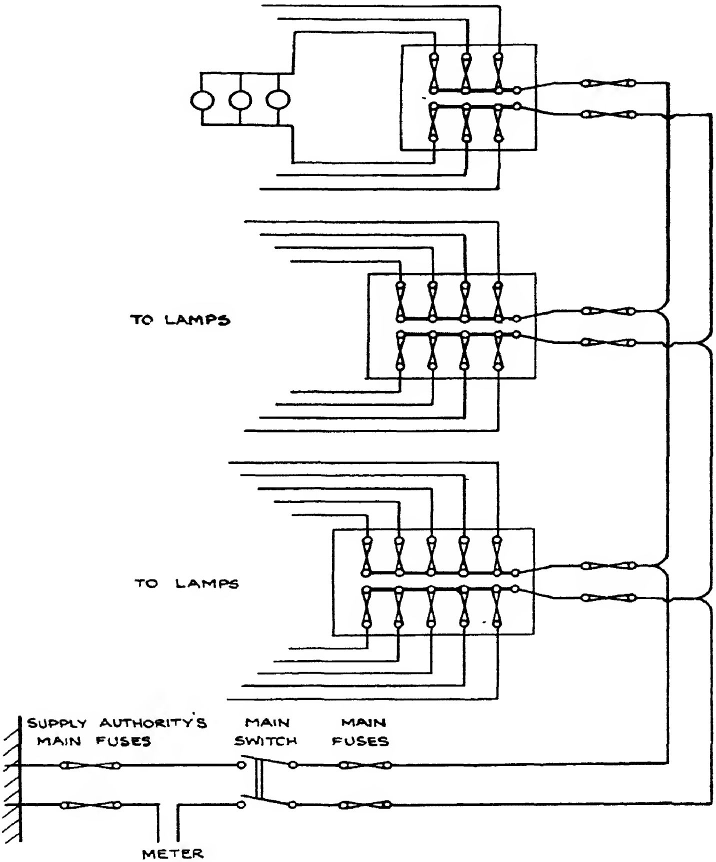


FIG. 72.—Feeders looped, but local fuses provided at each board.

two following points may, however, be taken as applying to *any* building:—

(*a*) That in all the important rooms or places, at least *two* circuits should be represented.

(*b*) The number of lamps per circuit should be kept as small as possible.

It is regrettable that each of these points is so often ignored by those responsible for the carrying out of installation work, with the inevitable results of inefficiency and inconvenience.

If the condition (*a*) is observed when designing the wiring, it will follow that, if a fuse blows, no important room or place will be left in *total* darkness. Even if the room or place concerned contains say only two lighting points, there will be no difficulty in putting these on to two separate circuits at the distribution board, though the circuits selected control lamps in other rooms. Unfortunately, the present-day tendency is to join up as many lamps which are adjacent to one another as possible, by looping from one lamp to the next, simply in order to save trouble and a little extra material.

(*b*) The smaller the number of lamps connected to one circuit, the smaller will be the number put out of action, as the result of a fuse blowing. The Regulations of the Institution of Electrical Engineers prescribe that when the maximum current from a final sub-circuit does not exceed 6 amperes, that the number of points connected to it shall not exceed 10. This is a very liberal allowance, and one which, in many cases occurring in practice, has to be considerably reduced, in order that fairly large areas shall not be plunged into darkness by the blowing of a fuse. When, for instance, the lamps employed are of 40 or 60 watt size, the number connected to any one circuit at the distribution board should, preferably, not exceed say 6. Where the lighting is carried out by gas-filled lamps of large size, such as 200 watts, or over, it is best to limit the circuits to say two lamps each and, in some cases, to only one lamp each.

'Spare Ways.'—It is always well, when settling the sizes of the distribution boards, to provide for one or more spare ways, in addition to those actually required for present lighting. Such spare ways are useful in case of future possible additions, the extra cost, if done at the time, being comparatively trifling.

Three-wire Circuits.—A three-wire system of wiring is one comprising three conductors instead of two, one of these being known as the 'neutral,' or 'middle,' or 'balancing' conductor, the others being always referred to as the 'outers.' The lamps are arranged to form two main circuits as near as possible, equally

loaded under normal working conditions, these being connected respectively between the neutral, and each outer conductor.

Voltage.—The voltage between the neutral and either outer is always half of that across the two outers, hence, when the consumer's load comprises both power and lighting, the former is connected across the two outers, excepting in cases where the motors are of very small size.

Neutral Conductor.—In practice it is very unlikely that the loads on the two sides of a three-wire system will be balanced, so that the neutral conductor will usually be carrying current. Fig. 73 will illustrate the various current conditions which may obtain in the neutral conductor.

(1) Assume that the loads 'A' and 'B' are on. There will then be no current through the neutral conductor, as the two loads are equal, and connected at the same position.

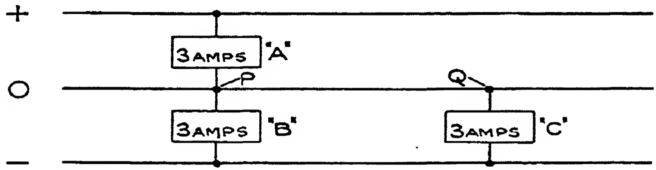


FIG. 73.—Diagram illustrating possible current conditions in a three-wire service.

(2) Assume that 'A' and 'C' only are on. There will still be a condition of balance, but current will flow along part of the neutral, that is, from P to Q.

(3) Assume that 'A' and 'B' and 'C' are on simultaneously, then the current through 'A' will be too small for 'B' and 'C,' and the extra current will therefore flow outwards along the neutral.

(4) Alternatively, if the load on the positive side be greater than that on the negative (as, for instance, if 'C' were transferred to the positive side), then the balance of current from the positive side not required by the negative would flow inwards to the source of supply.

It is essential that, at all times, the continuity of the neutral conductor be maintained as, otherwise, the balance of the system will be upset, resulting in the one side being considerably over-volted, and the other similarly under-volted. A consideration of the diagram Fig. 74 will illustrate this point. On the positive side

(+) of the system, it may be supposed that the load in lamps is equivalent to 10 amperes current, and that on the negative side (−) to 5 amperes. Should the neutral conductor (0) be broken at 'P,' then the load on the one side at once becomes in series with that on the other, with the result that the lamps on the + side will be under-volted, while those on the − will receive a corresponding excess. Taking the normal voltage values given in the diagram, Fig. 74, the numerical results may be calculated as

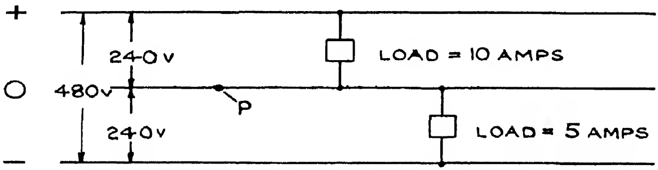


FIG. 74.—Diagram illustrating voltage variations with neutral conductor broken.

follows: Before the break in the neutral occurred, the current on the positive side was 10 amperes at 240 volts. The resistance of this side of the circuit would therefore be

$$\frac{240}{10} = 24 \text{ ohms.}$$

On the other side the current was 5 amperes at 240 volts, showing a resistance of

$$\frac{240}{5} = 48 \text{ ohms.}$$

When the break in the neutral has occurred, and the two loads are in series, their combined resistance will be

$$24 + 48 = 72 \text{ ohms,}$$

and the current which can pass will be

$$\frac{480}{72} = 6{\cdot}66 \text{ amperes.}$$

The voltages obtaining across the two sides of the system will be:

$E = I \times R$ or $E = 6{\cdot}66 \times 48 = 319{\cdot}68$ volts for the − side, and $E = 6{\cdot}66 \times 24 = 159{\cdot}84$ for the + side.

The chief reason for the adoption of a three-wire system as against a two-wire, is the amount of copper required for the transmission of a given load over a given distance. Approximately, only about $\frac{1}{3}$ of the quantity of copper is necessary, the

cross-sectional area of the neutral conductor being usually taken at about one half of that of the outers.

The fact that large motors may be connected across the outers of the system at double the lighting pressure is also an advantage as regards economy of copper.

Main Switches and Fuses.—Where triple-pole switches are employed in a three-wire system, they must be mechanically linked together, so that the neutral conductor cannot be opened unless the outers are also and simultaneously opened. With regard to fuses, it is not usual to have a fuse on the neutral con-

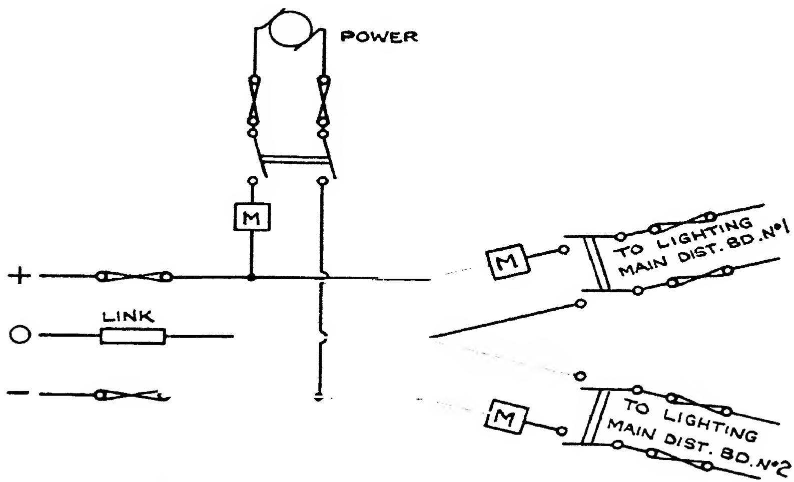


FIG. 75.—Arrangement of main switches, fuses, and meters on a three-wire system.

ductor, its place being occupied by a connecting-link of copper, whose section is at least equal to that of the conductor. This link provides a convenient method of disconnecting the installation from the source of supply, should this, at any time, be necessary.

Fig. 75 shows in diagram form the usual arrangement of switches, fuses, and meters on a three-wire system supplying both lighting and power.

Arrangement of the Distribution Boards on a Three-wire System.—In settling the positions of the two main distribution boards which are indicated in Fig. 75, care must be taken so that it shall not be possible for a person to make contact with the

'live' parts of both boards simultaneously, as this would obviously involve a shock at the full voltage which obtains across the outers of the system. To meet this point, the two main distribution boards should be fixed in positions well apart from one another or, alternatively, if this be not possible and they be fixed side by side, the doors may be made interlocking, so that it is not possible for these two boards (connected to the opposite sides of the system) to be opened at the same time.

Alternating Current Circuits. 'Single Phase.'—The single-phase system of alternating current supply is generally used as an ordinary two-wire system, as in the case of direct current, whether for lighting or power. For purposes of convenience, the one conductor is regarded as the positive and the other as the negative, although, of course, the polarity alternates between the two. This system is not one which is extending in use, the other alternating current systems referred to in the succeeding paragraphs presenting greater advantages.

Two-phase System.—In this system, two single-phase currents are impressed on the circuit. These two currents are, of course, equal in voltage, and also in their 'periodicity' or rate of alternation, but differ in phase being displaced from one another by a $\frac{1}{4}$ of a period or 90°. Usually, in a two-phase supply, two pairs of conductors are employed, each pair representing one phase, and therefore carrying half the total current. Consequently, all four conductors will be of equal section. In some cases, a two-phase supply is given through three conductors only, the third, or as it is sometimes called, the 'middle' conductor, acting as the common return for both phases. This return conductor will not be of twice the section of the outers but $\sqrt{2}$ or 1·414 times, for the reason that, although it is carrying two return currents, these two are not in phase.

In a two-phase system of supply, the lamps will be supplied from *either* phase, and power from *both* phases, the motors being two-phase machines. In large installations, the lighting load would be arranged to form two main circuits of approximately equal value, these being connected across the two phases respectively, thus balancing the load between them. The diagrams given in Figs. 76 and 77 illustrate the several connections referred to.

Three-phase System.—In this system the three single-phase currents, which differ from one another in phase only will, of

course, be at 120° apart. For this purpose, three conductors only will be required to convey the currents from the point of genera-

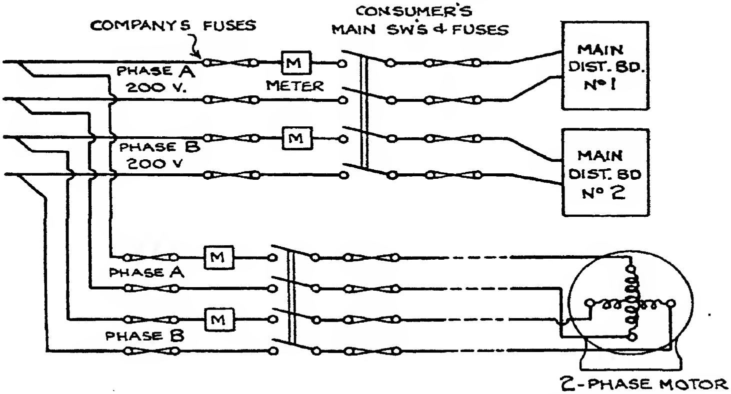


FIG. 76.—A two-phase four-wire circuit supplying lighting and power.

tion to the circuit, as it can be shown that the conductors of any two phases together form the return for the current in the remaining phase.[1] In many modern systems of three-phase

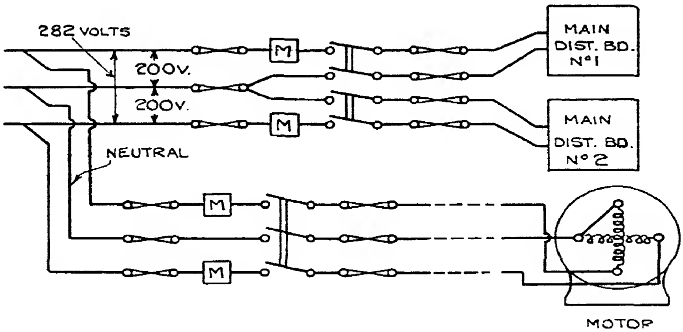


FIG. 77.—A two-phase three-wire circuit supplying lighting and power.

distribution, where lighting forms a considerable part of the load, it is usual to employ four conductors, three of these representing

[1] Care should be taken to distinguish between (1) a three-wire D.C. system, in which the neutral is of *smaller* section than the outers; (2) a three-wire two-phase system, in which the common return is of *larger* section than the others; and (3) a three-phase system, where the three 'phase' conductors are of *equal* section.

the respective phases, the fourth (or as it is usually called, the 'common' or 'neutral') conductor, being connected at the generating station to the 'centre' or 'star' point of the system, the lamps being connected between this fourth conductor and any one phase.

Under this arrangement, the line pressure does not exceed 430 volts, and the pressure for lighting not more than 250 volts. Motors, if three-phase, will be fed from the three-'phase' conductors, or small single-phase machines may be fed from one phase, and the neutral conductor in the same way as the lighting circuits.

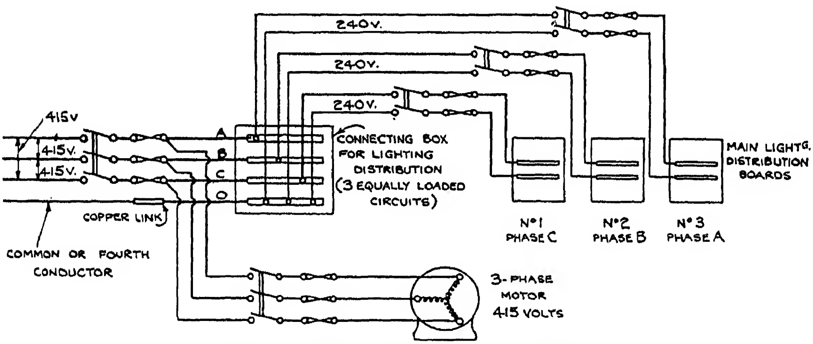


FIG. 78.—A three-phase four-wire circuit. (Lighting and power.)

Where the lighting installation is of appreciable size, it would be arranged to form two or three main circuits of approximately equal value, which would be connected respectively between any one phase and the neutral, so as to permit of the total load being balanced as near as possible between the three phases.

The diagram given in Fig. 78 illustrates the usual connections.

Arrangement of Distribution Boards Supplied from Two- or Three-phase Systems.—Where the main distribution boards are arranged to balance the load across the phases of the system, the same care must be taken as on a three-wire D.C. system, as regards protection from personal contact with high voltage parts.

SECTION III.

ACCESSORIES AND THEIR USES.

CHAPTER IX.

LAMPS.

(*a*) **Carbon Filament Type.**—In these lamps the bulb is exhausted of air, the filament, therefore, operating in a vacuum. The efficiency is low, being of the order of 3·5 to 4 watts per candle-power. Although no longer used for ordinary illumination purposes, they are still required for special cases, and are made in many different sizes. These lamps are usually described according to their rated candle-power.

(*b*) **Metal Filament Vacuum Type.**—These lamps differ from type (*a*) in that the filament is of Tungsten drawn wire. Their efficiency is approximately 1·2 to 1·5 watts per candle-power. For circuits of modern voltage (200 to 250 volts), the usual sizes range from 20 to 60 watts.

(*c*) **Metal Filament Gas-filled Type.**—In this type the bulb is filled with an inert gas (such as argon or nitrogen), which permits of the filament being operated at a much higher temperature and, therefore, at a higher efficiency than is possible with a vacuum lamp. In some sizes the efficiency approximates to half-a-watt per candle power. As a result of the high filament temperature, the light emitted is much whiter in colour. For circuits of 200 to 250 volts, gas-filled lamps are obtainable in sizes ranging from 40 to 1 500 watts.

Bulbs.—The modern gas-filled lamp, with its high intrinsic brilliancy, has emphasised the need for some means of obscuring of the glass bulb, in order to minimise the evil of 'glare' and to produce a more even diffusion of the light given out, particularly where no shade or reflector is used. External 'frosting' of the

bulb either partially or completely was the method first adopted. Of recent years, 'spraying' of the bulb with a transparent white enamel has been used with very great success. Colour-sprayed bulbs, for decorative purposes, are, likewise, equally successful. Spraying and frosting the outside of the bulb must, naturally, involve some loss in efficiency by absorption. The most modern form of obscuring consists in *internally* frosting the bulb. This

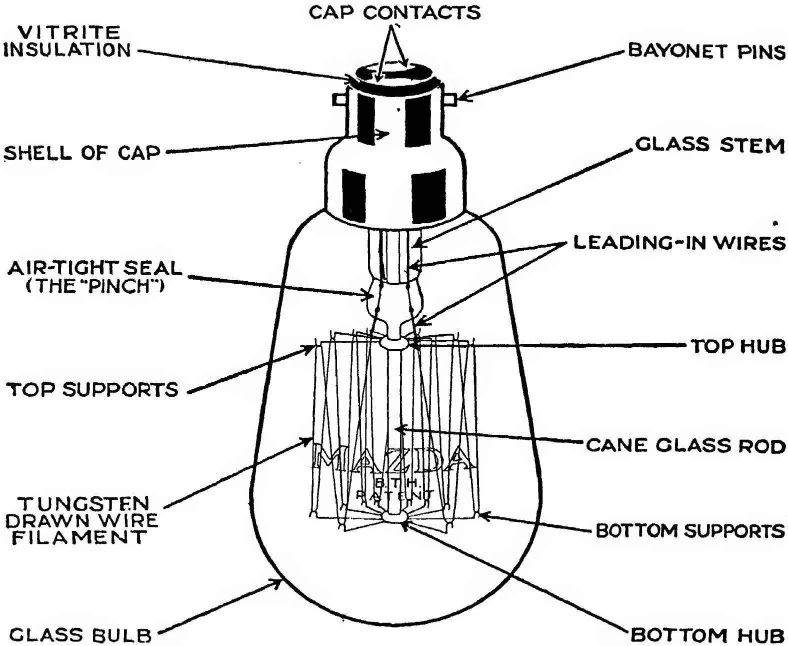


FIG. 79.—The several parts of a vacuum lamp. (Mazda.)

method has the great advantage of absorbing less light than outside frosting, whilst giving equal diffusion.

Tubular Lamps.—These are specially useful for such purposes as the lighting of shop windows, pictures, desks, etc., when combined with a shallow trough reflector. 20, 30 and 60 watts are the usual sizes in which these lamps are made.

Candle Lamps.—These, as their name implies, are intended for use in 'candle-fittings,' and are mostly made in 20-watt size.

The Neon Lamp.—This is not a 'filament' lamp, but [illegible] electrical discharge in neon gas, with which the bulb is filled. It is made in one size only, namely 5 watts. The light given out may be compared to a dull red glow, and it is only suitable, therefore, for positions where a very subdued illumination is required.

Lamp Caps.—All carbon filament lamps or M.F. vacuum lamps, or gas-filled lamps up to 100 watts in size, are fitted with

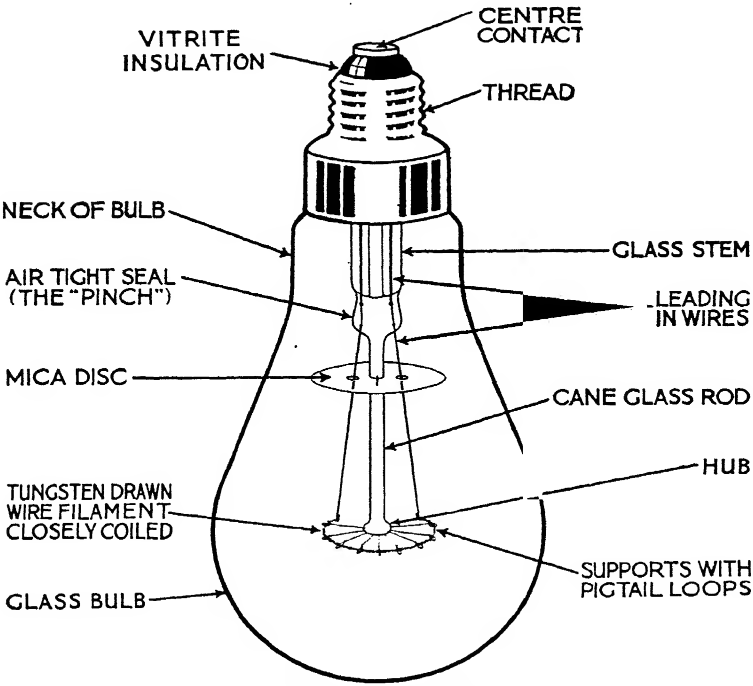


Fig. 80.—The parts of a Mazda gas-filled lamp.

standard bayonet or 'B.C.' caps, gas-filled lamps above 100 and up to 200 watts, having E.S. (Edison-Screw) caps, those above 200-watts size being fitted with 'Goliath' Edison-Screw (G.E.S.) caps.

B.C. caps have, of course, two contact plates, whereas any Edison Screw cap has but one centre contact plate, the screwed portion of the cap forming the other contact. The insulation

resistance, as measured between the contact-plate or plates of any lamp cap and the ring or case, should not be less than 50 megohms.

Figs. 79 and 80 show respectively the several parts of the vacuum and the gas-filled (centre contact) lamp.

Ventilation for Gas-filled Lamps.—In view of the rapidly extending use of gas-filled lamps, it is necessary to point out that the fittings in which these are used should always be so designed as to permit of a free dissipation of the greater heat which is always set up by this type of lamp.

CHAPTER X.

LAMP-HOLDERS.

THESE are of two standard types, to suit the lamp caps, as referred to in the preceding chapter, *i.e.*, the bayonet cap and the Edison screw cap. They may also be further described as either the plain holder to screw direct to the fitting; the same with the addition of a brass ring for carrying the lamp shade, and the holder which is provided with both a shade ring and a cord grip for use with flexible cord pendants.

The ordinary B.C. holder consists essentially of the following parts: the 'interior,' the brass case or 'liner,' which is provided with a bayonet socket for receiving the lamp cap; the 'dome' or top; and the screwed fixing or 'clamp' ring, to hold the several parts together. Additionally, when required, the shade ring and cord grip are provided. The standard 'interior' is the 'S'-type, and consists of a china base, on which is formed an S-shaped china wall, which serves to isolate the two plungers from one another. As these plungers represent the 'live' ends of the circuit, good isolation is required to prevent the possibility of an accidental short circuit. These plungers are, of course, provided with springs at the back, which keep them pressed down on to the top of the lamp cap, thus ensuring good contact. In Fig. 81 will be seen the component parts of a complete cord-grip, shade carrier lamp-holder.

The points to be looked for in a good class lamp-holder are :—

1. The case, or liner, to be of sufficiently heavy gauge, so as to be rigid and durable under working conditions. The two indentations or 'nibbing' on the sides of the liner must be sufficiently deep to ensure its remaining in its proper fixed position, relative to the china base, when the several parts of the holder are assembled.

2. The dome should preferably be a cast one.

3. The clamping and shade rings should be of substantial section.

4. The 'S'-interior should have a base of English vitreous china. The contact plungers should preferably be flat-ended, so as to offer the maximum area of contact to the lamp cap, and it is an advantage, if the fixing screw which secures the brass plunger block to the base, is fitted with a washer, as a further means of obtaining rigidity.

5. Where a cord-grip type of lamp-holder is employed, this should be drilled a suitable size to properly grip the flexible cord as used. Where 'workshop' type of flexible cord is used, one central hole is necessary.

In the foregoing notes reference has been made to the section of the metal employed in the manufacture of the holder. This

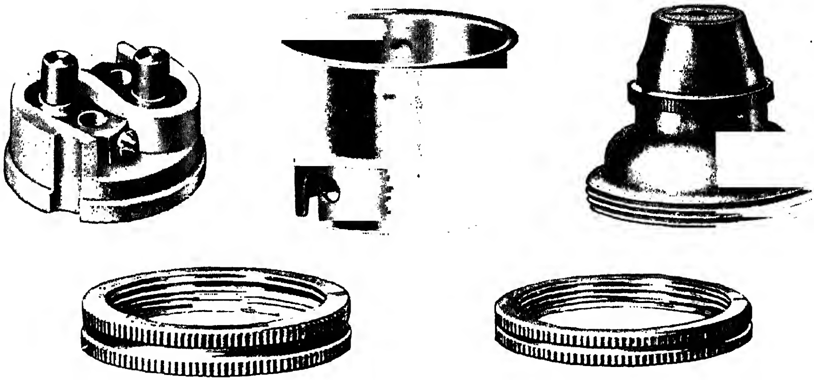


FIG. 81.—The parts of a cord-grip, shade carrier lamp-holder. (Tucker.)

point is one of great importance, if durability and good service are to be considered before cheapness in first cost. By way of comparison, it may be said that the ordinary light commercial cord-grip lamp-holder would weigh about 18 lbs. per gross, as compared with about 28 lbs. per gross for a high-class heavy gauge-holder, having a cast dome, and likewise of the cord-grip pattern.

Copper Lamp-holders.—For outdoor use, copper lamp-holders are necessary, as brass, particularly in the neighbourhood of towns and cities, deteriorates very rapidly on exposure to the atmosphere.

'Edison-screw' and 'Goliath' Lamp-holders.—These, as previously stated, are for use with lamps of high wattage. The

case, or liner, is provided with a very coarse screw-thread, for receiving the lamp-cap, which is similarly threaded. The holder-case, or liner, therefore, serves as the connection to one pole of the circuit, a centre stud being fitted within it, to make contact with the other pole, the lamps, of course, being always fitted with

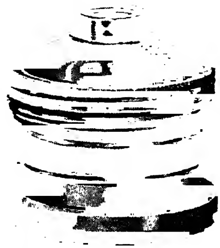


FIG. 82.—Edison screw lamp-holder.

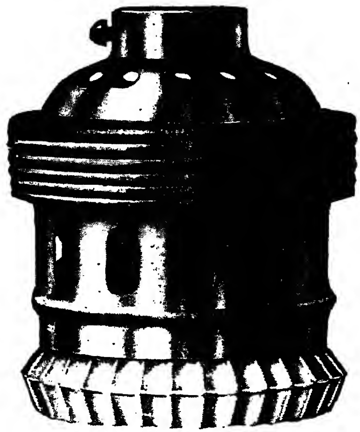


FIG. 83.—Edison Goliath screw lamp-holder.

a centre contact in the screwed cap. The advantage of the screwed lamp-holder is the very much greater area of contact which it provides, thus ensuring much cooler running than would be possible with a B.C. type. Illustrations of E.S. and Goliath lamp-holders are shown in Figs. 82 and 83.

Switch Lamp-holders.—This accessory, which is sometimes also

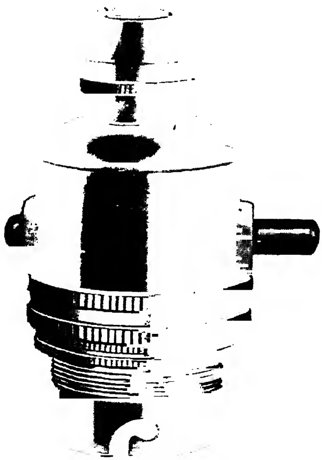


FIG. 84.—Push-bar pattern switch lamp-holder. (Tucker.)

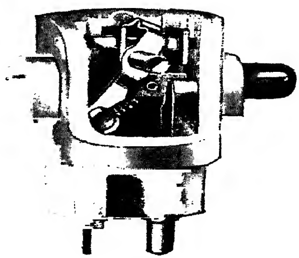


FIG. 84A.—Interior of switch lamp-holder showing switch movement.

described as a key socket lamp-holder, combines the duty of a lamp-holder with that of a switch. Fig. 84 shows a push-bar pattern, having a genuine switch action movement, this being, by far, the preferable type. Switch lamp-holders, though very convenient, and more or less essential where either table or floor standards are used, are not intended to serve as a substitute for the ordinary switch fixed on the wall. On the contrary, the latter is to be preferred, where possible. In a switch lamp-holder, many parts have to be contained in a very small space, and, further, also the flexible cord is always 'alive' right up to the lamp-holder. In this connection, it is useful to note that the I.E.E. Regulations

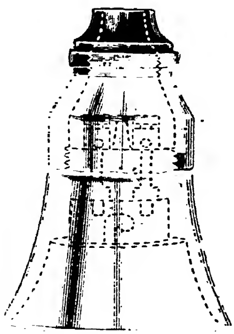


FIG. 85.—H.O. type lamp-holder (Ediswan).

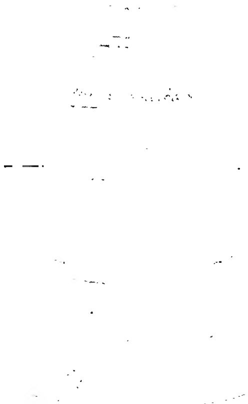


FIG. 86.—H.O. type switch lamp-holder (Ediswan).

prescribe that 'switch lamp-holders shall be provided with a further means of control in the same room.'

Special Lamp-holders.—For factory use, it is essential, in order to meet the requirements of the Home Office Regulations, that the exposed metal-work of the lamp-holders be earthed, or, alternatively, completely insulated, in order to provide protection from shock. The former treatment is rather inconvenient where flexible cord pendants are used, as it involves: (1) an earthing connection on the lamp-holder case, (2) the use of a three-core flexible (so as to provide an earthing wire), and (3) a three-plate ceiling-rose, one plate of which will be used as the junction for the earth connection. In most cases, therefore, insulated lamp-holders are

used. Figs. 85 and 86 show respectively a cord-grip shade carrier lamp-holder, and a push-bar type switch lamp-holder, suitable for factory use. It will be noticed that, in either case, the holder is completely shrouded in a jacket of moulded insulation, this being of a non-inflammable character.

Wiring of Lamp-holders.—When flexible cord is to be taken into a lamp-holder, the outer covering of silk or cotton must be stripped back, so that the vulcanised rubber only is in contact with the china interior. The bared end of the copper conductor will be twisted up tightly, and then doubled over, so as to properly fill the hole provided for it in the terminal, and thus make a tight and reliable connection.

Where a circular braided flexible cord is used, the wood cord-grip will be specially drilled to receive the braiding, and in the case of C.T.S. flexible, the whole of the rubber sheathing.

Where a lamp-holder is screwed direct on to a fitting, it is best, if possible, to take the hard V.I.R. conductors direct into the lamp-holder terminals.

CHAPTER XI.

CEILING ROSES.

A CEILING rose consists of a china base, on the front of which the brass plates or contacts are fixed. To these plates the incoming conductors are taken at one end, the flexible cords being attached to the other. Between the plates a bridge, or dividing wall of china is formed, which serves to isolate the plates of opposite polarity from one another. This bridge is provided with small

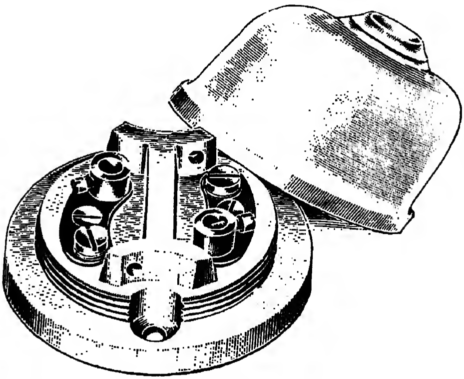


FIG. 87.—Two-plate ceiling rose. (Sax.)

holes, through which the flexible cord passes, thus providing a means of taking the weight of the fitting from off the small set screws which secure the flexible cord. An illustration of an ordinary two-plate ceiling rose is shown in Fig. 87.

Entrance Holes for the Conductors.—All ceiling roses are now so made as to allow of 'looping-in,' that is to say, the holes in the base are large and bell-mouthed on the back-side, so that two or more wires may be received into each of the circuit wire

terminals, if required. The object of 'looping-in' is, of course, the avoidance of joints in the conductors. The two sketches, (Figs. 88 and 89) show respectively three lamps wired on a looping-in system, and three wired with joints in the conductors, which latter method is now obsolete. In Fig. 88 it will be noticed that both the ceiling roses and the switches are looped.

Wherever looping-in is resorted to, care must be taken that each contact is thoroughly well made, as a disconnection at a looping point obviously affects every other point beyond which is looped with it.

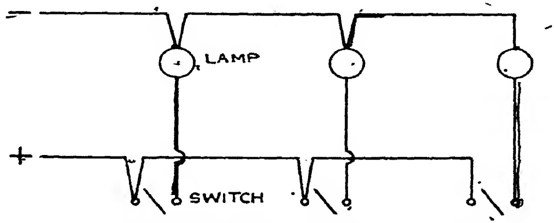


FIG. 88.—Lamps wired on looping-in system.

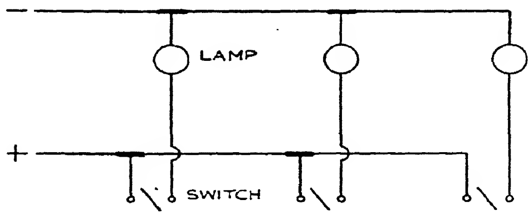


FIG. 89.—Lamps wired with jointed connections.

Three-plate Ceiling Roses.—These serve a very useful purpose where (*a*) it is intended to control a cord pendant cluster of lamps by two switches, or (*b*) where it is desired to loop the switch wires *at the ceiling rose*, instead of at the switches. Figs. 90 and 91 illustrate the connections of these two cases.

When one of the plates of a three-plate ceiling rose is to be connected to earth, it is essential to be able to readily identify it. To meet this condition, Messrs. J. H. Tucker & Co. have introduced a three-plate ceiling rose, having each of the plates differently shaped. A plan view of the base of this is shown in

Fig. 92. This custom of marking the three plates is in accordance with the British Engineering Standards Association Speci-

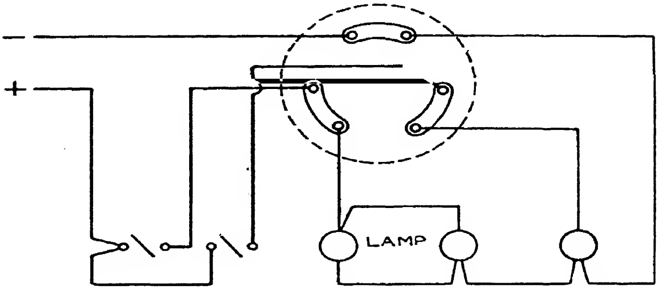


FIG. 90.—Connections for three-plate ceiling rose with two switches.

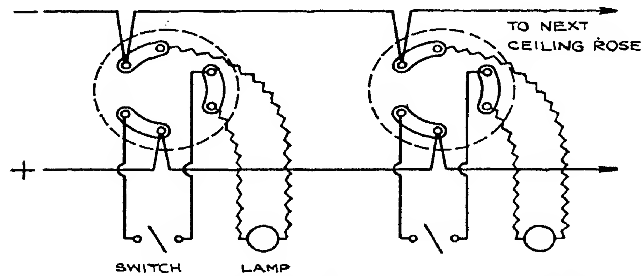


FIG. 91.—Connection for three-plate ceiling rose as used for looping both conductors.

fication for this class of rose, when intended for use under the Home Office Regulations.

The points to look for in a good quality ceiling rose are :—

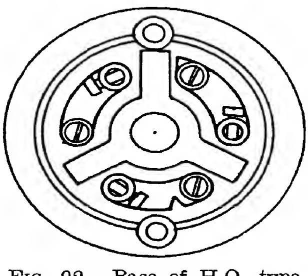


FIG. 92.—Base of H.O. type three-plate ceiling rose.

(1) The base to be formed of English vitreous china.

(2) The plates and their terminals to be of heavy section, the screws for the flexible wires being fitted with washers, to ensure as good a contact as possible.

(3) A good design of china cord grip, so that the weight of the fitting may be taken from off the terminals.

'Cleat' Ceiling Roses.—For a cleat system of wiring, as referred

to in Chapter VI., a special pattern of ceiling rose is obtainable. An illustration of the pattern made by the British Thomson Houston Company is shown in Fig. 54, Chapter VI. In this it will be noted that the cover is not screwed to the base, but is held in position by the two contact tongues which are mounted on it, engaging in the spring clip contacts of the base, this being effected by giving the cover half a turn. The cover of the rose, therefore, carries the flexible cord, and can be wired up from floor level before being placed in position, which is a point of considerable advantage. A further advantage is that no drilling of the wood Ceiling Block is necessary, as the conductors enter and leave the base of the rose direct through the two grooves, which are provided on either side of it.

Wiring of Ceiling Roses.—Where a V.I.R. conductor is to be taken into a ceiling rose, its end must first be properly prepared in the following manner: About ½ an inch of the conductor having been completely bared, the tape and the braid will be removed for a length of about one inch, so as to enable the bared end of the conductor to be taken into the terminal whilst only the vulcanised rubber is allowed to be in contact with the china. Every care must be taken to keep the tape and the braid clear of the china, as these materials, being of a fibrous nature, readily take up any dampness collecting on its surface. If one conductor only is going into the wire terminal of the rose, it is usually necessary to first double over its end, so that it may better fill the hole in the terminal, and thus afford a more reliable and rigid connection. This will certainly apply to such conductors as 1 / 044, 3 / 029, and 3 / ·036. The ends of the flexible cord will be trimmed in a similar manner to the hard wires, and it is essential to well-twist the strands together, before passing them under the washer of the cheese-headed terminal screw.

CHAPTER XII.

LAMP SWITCHES.

Tumbler Type.—For controlling small circuits of lamps, this type of switch is of general adoption in this country. Fig. 93 shows an ordinary single-way tumbler switch of Messrs. Tucker's pattern, with the usual flat brass cover removed. Many different designs of tumbler switch exist, but the following are the essential parts which are common to those of all makers: the china base; the bracket carrying the switch mechanism, and the spring clip contacts in the base, and their terminals.

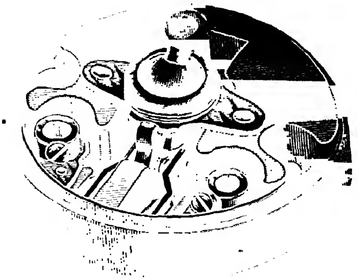


FIG. 93.—Single-way tumbler switch with cover removed. (Tucker.)

The points to be looked for in a good quality tumbler switch are:—

(1) The base to be made of the best English vitreous china.

(2) *Insulation.*—The insulating material which serves to insulate the actuating lever or 'dolly' from the current carrying part should be as good and as permanent in character as possible, and unaffected by either heat or moisture. Mica and 'marmorite' are mostly used in this connection.

(3) The contacts should be ample in size, double, and preferably tinned, to obviate corrosion, the metal employed being either copper or phosphor bronze.

(4) The terminals should provide for ready access when wiring, and their screws be flat-ended.

(5) The switch mechanism should provide for a positive 'hold-on' of the contact lever, as well as a positive 'hold-off.'

(6) *Quick-make-and-break.*—All modern switches are designed to be of quick-break action, but switches which are *quick-make*, as

well as quick-break, are now becoming generally necessary, in view of the extending use of gas-filled lamps.[1]

Earthing Terminals.—Many tumbler switches are provided with an earthing terminal, in order that the dolly-knob, and therefore any exposed metal-work of the switch (that is, the metal cover), may be properly earthed. This is desirable in most cases, but essential in factory work. An illustration of a surface pattern tumbler switch, fitted with an earthing terminal, is shown in Fig. 94.

The connection from this terminal to earth is best made by means of a wire connected at its other end to the steel conduit work of the wiring system, which conduit will, in any case, be earthed.

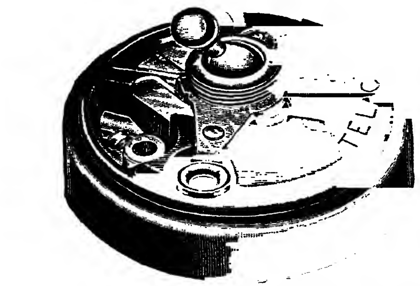


Fig. 94.—Surface type tumbler switch with earthing terminal. (Tucker.)

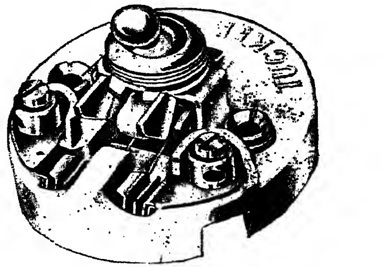


Fig. 95.—Sunk type switch showing provision for earthing. (Tucker.)

A convenient method is to solder the earthing wire on to a brass bush screwed on to the end of the conduit from which the conductors emerge, this wire being taken through a small hole drilled in the wood fixing block.

Where the wiring system is a metal-cased one, connection will best be made to the sheathing of the conductor by means of a suitable clip.

Switches of the sunk type are usually arranged to be earthed by means of the metal screws, which fix the switch itself to the iron box. An example of this is shown in Fig. 95.

[1] Any switch, to be efficient when used on circuits of gas-filled lamps, must make a practically instantaneous full contact, so that the extra surge of current which occurs in such circuits at the instant of switching on, may be carried through the *whole area of contact*, and not through a mere tiny point of contact, as might readily occur with slow-make switches.

Current Carrying Capacity.—Most makers rate their tumbler switches as either 5 or 10 ampere size. In a few cases, 1, 2, or 3 ampere sizes are made. It should, however, be remembered that many of the ordinary tumbler switches described as '5 ampere' are quite unsuitable for carrying this current. Although the area of the contact of the switch may be $\frac{5}{16} \times \frac{1}{4}$ inch, usually only a small proportion of this area is in actual contact—frequently only a point, through which all the current has to be taken.

Patterns.—Tumbler switches may be 'surface' pattern, having a china base about $2\frac{1}{4}$ inches in diameter, and intended for mounting on a hard wood block fixed on the surface of the wall, or where the wiring is concealed, 'small base' or 'sunk' pattern switches are used, whose china base is of about $1\frac{7}{8}$ inches diameter. These are mounted in iron boxes which are fixed beneath the surface of the wall, so that only the actual knob of the switch projects, the opening of the box being covered by means of an ornamental plate.

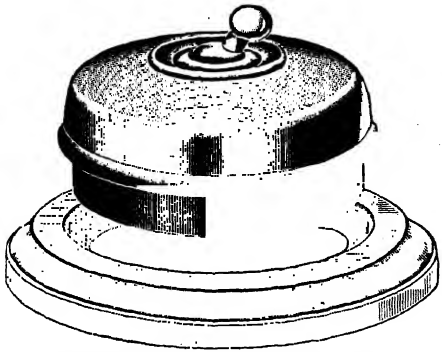


FIG. 96.—Semi-sunk switch and block. (Tucker.)

A pattern which is between the two foregoing, is the 'semi-sunk' or 'semi-recessed.' In this, the china base is recessed into a wood block, so that only the top edge of the former is seen. The surface switch is shown in Fig. 93. Illustrations of the sunk and semi-sunk patterns are given in Figs. 95 and 96 respectively.

Multiple Way Switches (Two-way).—It is frequently required to be able to control a lamp or lamps from two positions instead of one. In such a case, two 'two-way' switches are used, an illustration of this variety being shown in Fig. 97. It will be noticed that of the four terminal posts, the two on one side are linked together, thus forming one, which is known as the 'common' terminal of the switch, being common to each of its two ways. This will be rendered clear on reference to Fig. 98 which shows how the wiring is arranged. It will be noticed that there is no definite 'off' or midway posi-

tion in this switch, this not being necessary, as, if the lamp be alight, as the positions of the switches in the diagram show to be the case, whichever one is turned into its other position will have the effect of extinguishing the lamp. Likewise, when the lamp is out, whichever switch is turned will have the effect of relighting it.

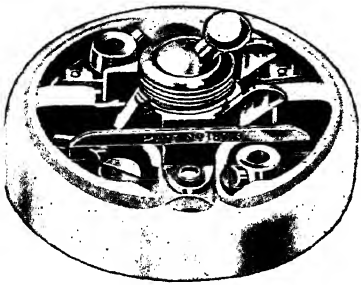


FIG. 97.—Two-way surface type switch. (Tucker.)

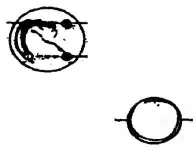


FIG. 98.—Connections for two-way switching.

Two Way-and-Off Switches.—The two way-and-off switch is a variation of the ordinary two-way. As its name implies, it is provided with a middle or off position. It is used where it is desired to light up either one of two lamps or circuits, but never both at once. The wiring diagram is given in Fig. 99. An example of this might be a bedroom containing two lamps, being one at the dressing table and one in the centre of the room, or at

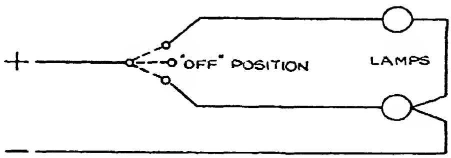


FIG. 99.—Connections for two way-and-off switch.

the bed, either of which could be lighted, but not the two together.

The Intermediate Switch.—This switch is one which, when used in conjunction with two two-way switches, enables a lamp or circuit to be controlled from three positions. An illustration of an intermediate switch as made by Messrs. Lundberg is shown in Fig. 100 and the diagram of its wiring connections for three-point control is given in Fig. 101. It will be noticed that the switch

has four contacts, the two positions causing the connections to be made either as per the full lines or, alternatively, as per the dotted ones. Any desired number of intermediate switches can be used in the wiring system between the two end (two-way) switches, each one giving an independent control of the lamp or circuit. Thus the switching of a lamp from four positions is shown in the diagram Fig. 102. In each of the last two diagrams the connections show the lamp to be alight, and it will be noticed that it can be extinguished by turning any one of the switches into its other position.

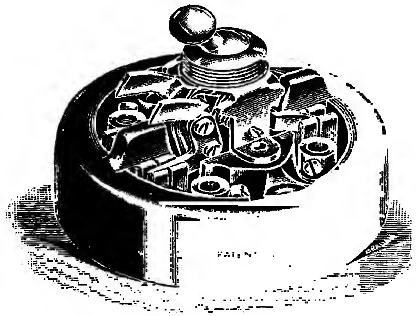


FIG. 100.—Intermediate switch—surface type.

'Master Controls.'—Any two-way or two-way and intermediate switching can be arranged with a 'master control.' This will consist of an ordinary single-way switch added to the circuit, its function being (*a*) to put the lamp *on* and prevent its being turned *off* at the other switches, or (*b*) to put the lamp *off* and prevent its being turned *on* at the other switches. Generally,

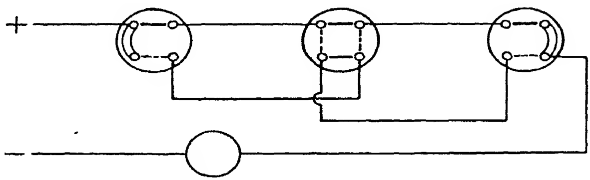


FIG. 101.—Connections for two-way and intermediate switching (three-point control).

therefore, it will be fixed in a place which is only accessible to a certain person or persons. The diagram given in Fig. 103 shows a circuit controlled by two two-way switches and one intermediate, together with two master control switches marked *A* and *B* respectively. It will be noticed (1) that if *A* and *B* be turned off, all the other switches are inoperative, and therefore the lamp cannot be turned on. (2) If *A* and *B* be turned on, it will

Sat—A.C. m

prevent the lamp being turned off by anyone operating the other switches. (3) If *A* be left on and *B* be turned off, the other three switches can then be used in the ordinary way.

The foregoing is but one of the many possible master control circuits which can be devised to meet special requirements.

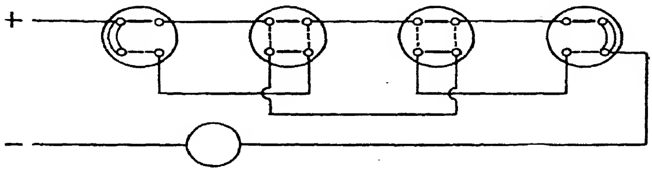


FIG. 102.—Connections for a four-point control (two-way and intermediate switching).

'Series-Parallel' and 'Whole-or-Part' Switches.—Amongst other multiple way switches in common use may be mentioned the 'Series-Parallel' and also the 'whole-or-part.' These two types, as made by Messrs. Lundberg, are shown respectively in Figs. 104 and 105 and their wiring connections in Figs. 106 and 107. By means of the first, it is possible to put two lamps (or circuits) in series for dim lighting or, alternatively, in parallel for full light. This switch may be had either with or without an off

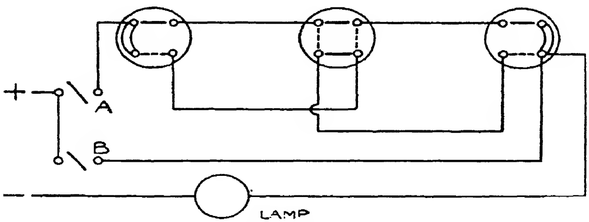


FIG. 103.—Two-way and intermediate switching, with master control.

position, the diagram showing the former. In the 'whole or part' switch, the functions of two switches are combined in one, the one position giving part of the circuit only in use, and the other position the whole, there being also a mid or 'off' position with the knob vertical.

Other Patterns of Tumbler Switch.—'Pear' or 'Pressel' Switches. These are used where the switch is intended to be

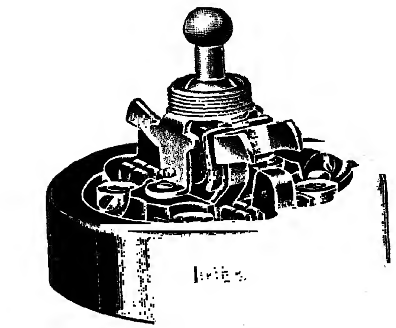


FIG. 104.—'Series-Parallel' surface type switch, with "off" position.

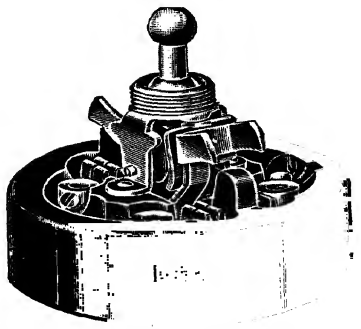


FIG. 105.—Whole-or-part surface type switch, with "off" position.

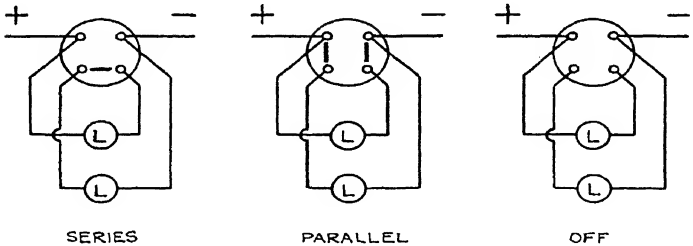


FIG. 106.—Connections for 'Series-Parallel' switch control.

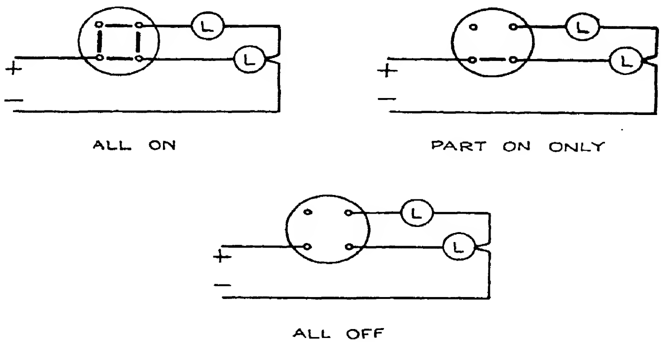


FIG. 107.—Connections for 'whole-or-part' switch control.

hung pendant from a flexible cord, the other end of which is attached to a rosette fixed on the wall. Fig. 108 shows a Pear

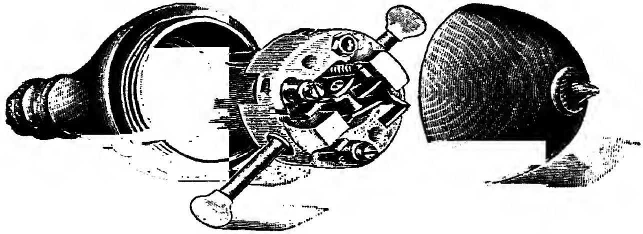


Fig. 108.—Pear switch showing a view of the interior.

switch by Messrs. Tucker, with its several parts laid out. In this pattern the action is on a tumbler switch principle, and is operated by an insulated push bar. In Fig. 109 the parts are shown assembled. The outer case is of polished hard-wood, ivory, ivorine, or similar material. Pear switches may be had either single or two-way, and are mostly used for controlling a bed-light.

Automatic Door-switches.—These are made in two patterns, (*a*) those that make contact when the plunger is pressed in, and (*b*) those which make contact when the plunger is allowed to protrude. The former pattern is largely used for controlling lavatory lights. It is fitted on the door framing, opposite the ordinary brass bolt, so that, as the person bolts the door on entering, the lamp lights up. Fig. 110 shows this pattern of switch, and Fig. 111 the same contained in a brass case, into which the door bolt enters. The other pattern (*b*) is useful for fitting into the jamb of a door, so that the light is turned on when the door is opened. Care should be taken, when fixing these automatic door switches, that the exposed metal-work is efficiently earthed.

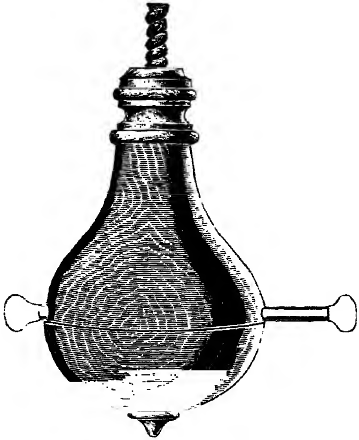


Fig. 109.—Complete pear switch.

'Shock-proof' Tumbler Switches.—To meet special cases where the earthing of the exposed metal-work of switches cannot be effectively done, it is now possible to obtain surface type tumbler switches in which the knob, the cover, and its fixing ring are made of a moulded insulating material. The switches are particularly useful for such positions as bath-rooms, sculleries, kitchens, etc. The moulded covers are unbreakable, and do not deteriorate under the conditions which prevail in such places.

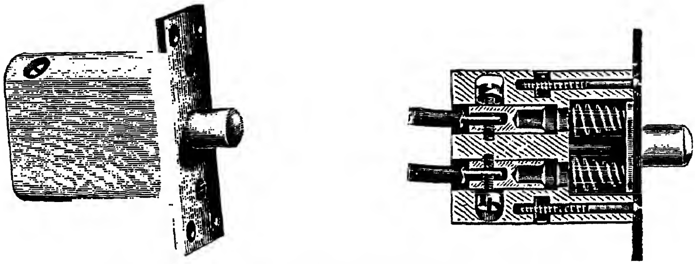


FIG. 110.—Automatic door switch. (Lundberg.)

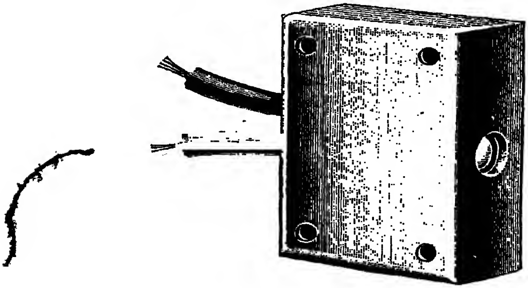


FIG. 111.—Automatic door switch contained in a brass case. (Lundberg.)

Ironclad and Watertight Tumbler Switches.—For positions subject to rough usage, and where the wiring work is on the surface, it is usual to employ small base switches contained in a cast-iron box, as shown in Fig. 112. The spout of the box is tapped and butt-ended internally, so that the conduit cannot project into the interior, the cable entry being bell-mouthed to prevent abrasion of the switch wires. The dolly of the switch automatically becomes earthed to the cast-iron box. In the watertight pattern of tumbler switch, likewise intended for surface wiring, the cast-

iron case is fitted with a lid which has a stuffing box and gland, through which the spindle rotates. A rubber packing ring is provided between the box and its lid. The switch is of the tumbler

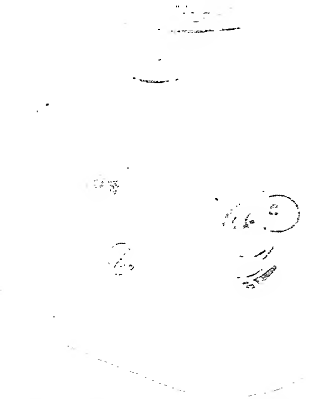


FIG. 112.—Ironclad tumbler switch. (Tucker.)

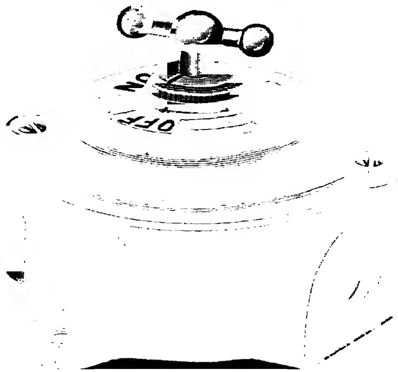


FIG. 113.—Watertight ironclad tumbler switch. (Tucker.)

type, although the movement is actuated by a nickel-plated turn handle, as shown in the illustration Fig. 113.

Push-button Momentary Action Switches.—These are made both in the tumbler and other patterns, and being of

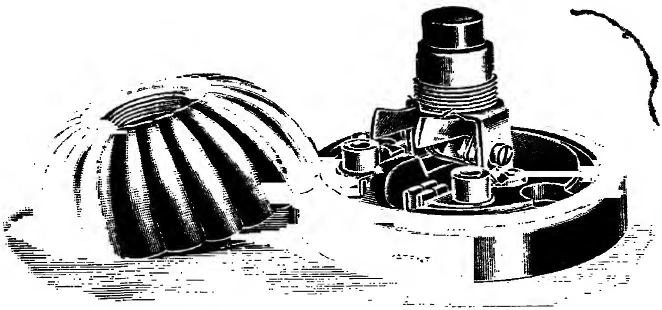


FIG. 114.—Push-button momentary action switch (5 amps.).

momentary contact only, are not intended for use as ordinary lighting switches. They have, however, a wide application for such purposes as: flash signalling (with one or more lamps); and

in the circuits of 'push-button' electric passenger or other lifts; electric motors driving printing presses and other machinery; electrically operated main switches, circuit breakers, etc., where the circuit being normally either opened or closed, has to be either closed or opened so long as the button is depressed. Two patterns, as made by Messrs. Lundberg are shown in Figs. 114 and 115, these being of 5 and 10 ampères capacity respectively.

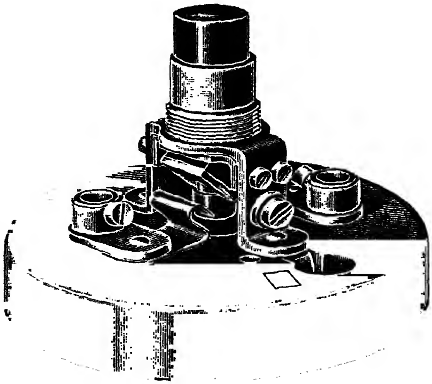


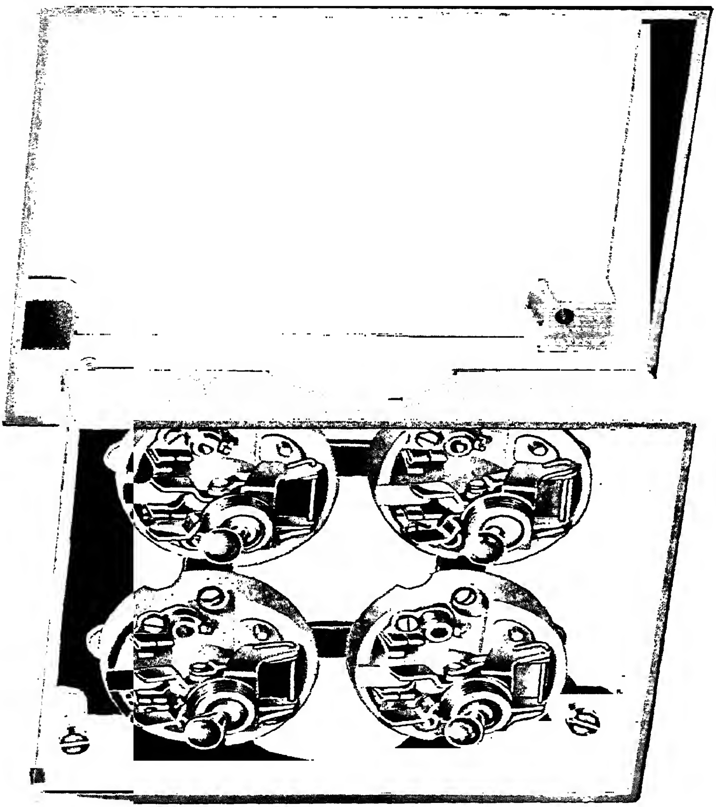
FIG. 115. Push-button momentary action switch (10 amps.).

Similar switches to these, but in a very light design, are made for ordinary electric bell work, to serve in place of the old-fashioned bell push. For this duty they are obtainable either in the surface, sunk, or semi-recessed patterns, their covers being finished to match the lighting switches.

Polarity of S.P. Switches.—In the wiring up of single pole lamp switches, whether these be single way, or any form of multiple way, care should be taken that they are all connected to the same pole of the circuit, this pole being the positive or 'live' wire, for which red conductor is always used. Unless this were done, there would always be a possibility of leakage from the fittings or the greater portion of the circuit, even when the lamp were switched off. In this connection, a useful rule for the wireman to follow is 'red from a switch or to a switch.' The strapping wires between the two-way or the intermediate switches should likewise be chosen red, although some wiremen insist on using black in these positions, to distinguish them from the switch 'feed' or the lamp 'feed.' This is quite unnecessary, as a simple bell-and-battery test will quickly obviate any doubt in the matter.

Wiring and Connecting of Switches.—Care must be taken in passing the V.I.R. conductor into the switch, to see that the tape and the braid are sufficiently cut back, so as not to come into contact with the china base. The wire, when it is passed into the terminal, should be bent over at the top, so that its end does not

project and touch either the metal cover or any other part of the switch, this being a very usual kind of fault. Terminal screws should never be slack in the thread, and should always firmly grip



box.

the wire, as switches, wherever mounted, are always subject to vibration.

Mounting and Fixing of Switches.—For surface wiring, switches are mounted on hard-wood blocks, these being usually

chosen of teak or beech, and recessed at the back to facilitate the passing in of the conductors. The semi-recessed switch is provided with a block, which is bored out in the centre to the full diameter of the bottom of the china switch base, so that it virtually becomes a wooden ring or mount, the switch itself, when fixed, serving to hold it in position. This applies, whether the block be circular or square. An illustration of this is given in Fig. 96.

In the fixing of sunk (or small base) switches, special care is necessary if a really good job is to result, owing to the variations in the thickness of the plaster, which is often found, even in different parts of the same building. To meet this case, the lead-

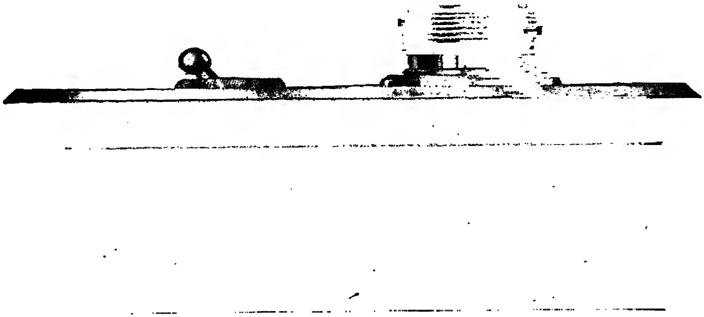


FIG. 117.—Switch and plug box showing liner raised. (Walsall.)

ing manufacturers have introduced 'adjustable grids.' An example of one of these, by the Walsall Company, is given in Fig. 116, where it will be seen that the switches are carried on a 'grid' or 'cradle,' which forms an adjustable liner to the iron switch box, the required adjustment being obtained by slacking out or tightening up the screws provided. In Fig. 117 is shown a switch and plug box with liner raised to accommodate the irregularity in the plaster.

Positions for Fixing Switches.—In most cases, switches are fixed inside the room whose lamps they are to control. Exceptions to this worthy of note are safes and strong rooms, where it is desirable that they should be fixed external to the room; and in certain factories, where explosive gases are likely to be present in the atmosphere—it is also desirable that no switches be allowed inside.

Automatic Time Switches.—This apparatus is used where it is necessary to light a lamp or lamps and to extinguish same at prearranged times. It consists of a switch which is opened or closed

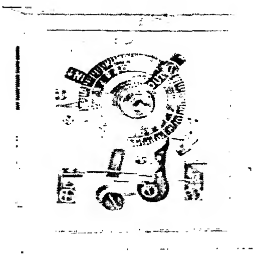


Fig. 118.—Venner automatic time switch.

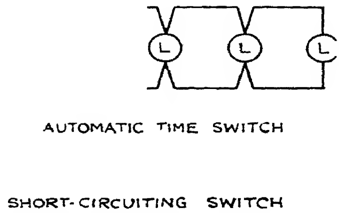


Fig. 119.—Circuit controlled by automatic time switch.

by the action of a clock, which may be set to operate at any hour desired. An illustration is given in Fig. 118 which shows one of the many patterns made by Messrs. Venner. The apparatus is

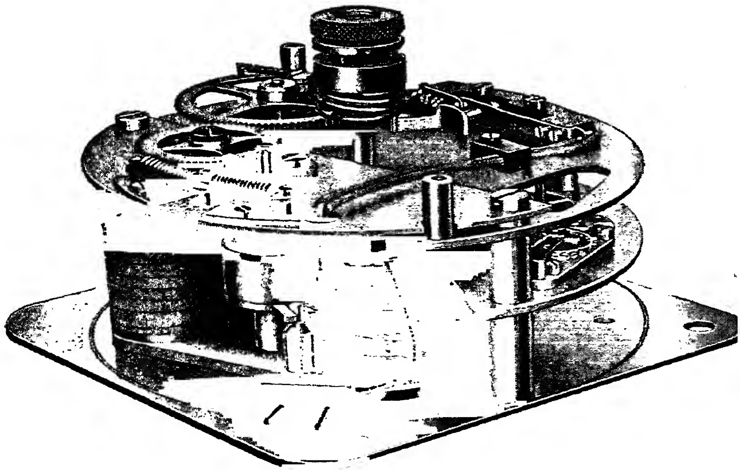


Fig. 119a.—Electrically wound time-switch clock.

placed in series with the circuit, and acts as a master control to same. Local switches of the ordinary type, controlling a part or parts of the circuit may, of course, be used in addition. In view of

the fact that the times of operation of a time switch may be varied at will, frequently or infrequently, it has many spheres of usefulness, as, for example, in controlling shop window lighting during the closing hours, or the lighting of the servants' quarters of a country house, for public staircase lighting in blocks of flats or offices, and for operating factory hooters, etc. Fig. 119 shows a diagram forming a circuit of selected lamps forming part (or all) of a shop window lighting scheme controlled by a time switch. The connections to this latter are shown provided with a short-circuiting switch, which enables the lighting to be controlled in the ordinary way during the usual hours of business.

Electrically Wound Time-switch Clock.—In order to avoid the necessity of continually re-winding by hand the clock of the time switch, Messrs. Venner have recently introduced an electrically wound clock operated by a special motor which only requires 3 watts for about 15 seconds and at about 8-hour intervals. Originally designed for an A.C. circuit, it is said to work equally well on a D.C. supply. An illustration of this clock with its cover removed is given in Fig. 119A.

CHAPTER XIII.

PLUGS.

A PLUG, sometimes wrongly called a 'socket,' consists essentially of two parts; the fixed part which may, if desired, be called the socket, and the movable part or 'top.' To the former will be attached the circuit wires, which bring in the current, and to the latter, the flexible cord, or cable, to which is attached the portable apparatus, such as a table lamp, floor lamp, heater, etc. An ordinary two-pin plug of the surface type is shown in Figs. 120 and 121. The essential parts of this plug are: The china base for the fixed or 'socket' portion, on which are mounted the two contact tubes with their blocks, each being fitted with a terminal screw for securing the incoming conductor. The two blocks are, of course, well isolated from each other by the formation of the china base. The top, or plug, portion will be made in china or hard-wood, and have an insulating base of fibre, which will be

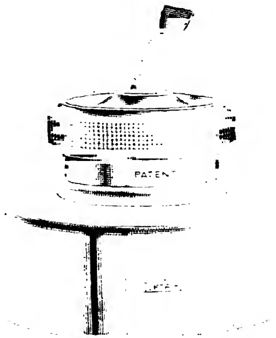


FIG. 120.—Ordinary two-pin plug as assembled. (Lundberg.)

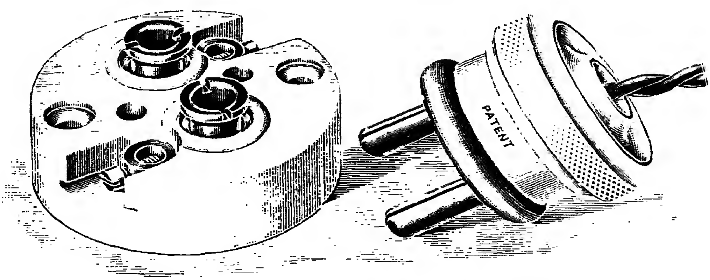


FIG. 121.—Parts of an ordinary plug. (Lundberg.)

fitted with the two pins and their terminals. The holes in the top will be so formed or drilled so as to provide a natural cord-grip, and thus relieve the terminals of the pins of any direct pull on the flexible cord.

The points to be looked for in a good quality plug are:—

(1) The base to be of English vitreous china.

(2) The contact tube and block should be so designed that current is not required to pass through screw-threads. The same remark applies equally to the pins and their terminals. An illustration is given in Fig. 122 which shows two alternative methods of construction, the old and the new, the latter being the one now adopted by Messrs. Julius Sax & Co.

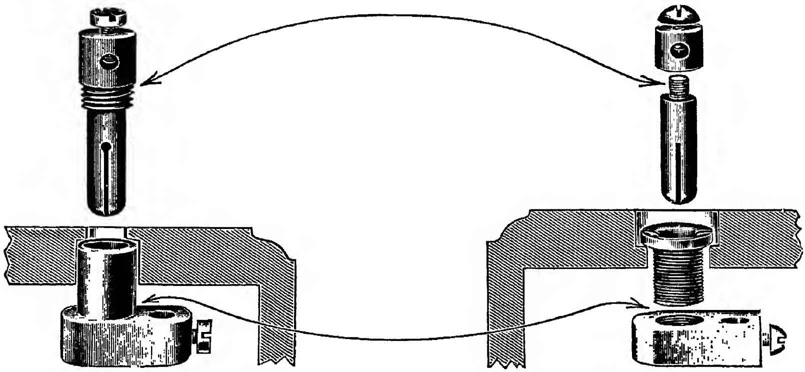


FIG. 122.—Alternative methods of construction for plug tubes and pins.

(3) The contact tubes should be recessed well below the level of the china or other cover.

(4) All parts of the plug should conform with the standard specification of the British Engineering Standards Association.

Sizes.—The standard sizes to which plugs are commonly made are: 2, 5, 15 and 30 amperes. For special purposes, however, such as factory or dockyard work, plugs are obtainable of sizes up to 250 amperes.

Switch Control of Plugs.—Every plug of whatever pattern or size should preferably be controlled by a switch close at hand. The reason for this is that a plug is an apparatus which is not so constructed that it is suitable to be used as a means of breaking the circuit, as is a switch. Further, also the Regulations of the

Institution of Electrical Engineers[1] prescribe that 'every socket or group of sockets carrying more than 300 watts shall have a switch in an accessible position.' In order that the ordinary user shall not be able to ignore the principle of switch control to a plug, many designs of plugs which are interlocked with a switch are now obtainable in which it is impossible to insert the plug top into a 'live' socket, and equally impossible to withdraw it from a 'live' socket. These, however, will be referred to later.

Hand-shield Plugs.—This pattern of plug top is rapidly coming into use for lighting and heating circuits. An illustration is shown in Fig. 123. Owing to the fact that the flexible cord enters *at the side,* it is impossible to remove the top from the socket by pulling on the cord, a condition much to be desired. Further, also the hard-wood disc or shield protects the hand of the user against the effect of any arcing of the pins, should the plug top be withdrawn whilst the current is on.

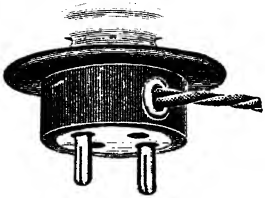


FIG. 123.—Hand-shield plug top. (Sax.)

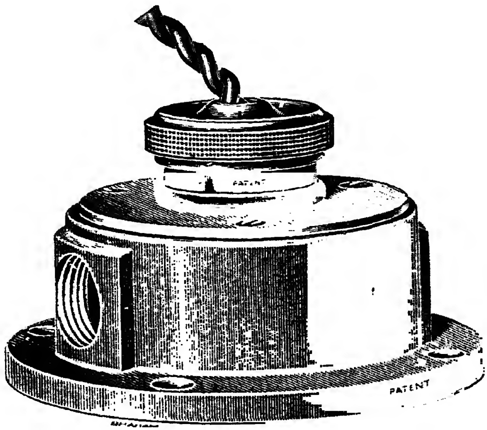


FIG. 124.—Iron-clad two-pin plug.

Iron-clad and Watertight Plugs.—(Two-pin Pattern.) For positions where a robust construction is essential, iron-clad plugs are adopted. Fig. 124 shows an example of one of these by Messrs. Lundberg, the top, however, being usually fitted with a hand-shield. Fig. 125 shows another variety, where watertightness is obtained by means of the brass cap, which is screwed down after the plug is inserted. When the plug is not in use, a brass cover is screwed over the contact tubes.

[1] All the provisions of Regulation No. 112 (I.E.E.) should be carefully studied.

Three-pin Plugs.—The type of plug which is commonly known under this name is one which, in addition to the two contact tubes and pins for carrying the current, is provided with a third, for the purpose of earthing.

The importance of the efficient earthing of metal conduit and the metal-work connected to it has already been emphasised in an

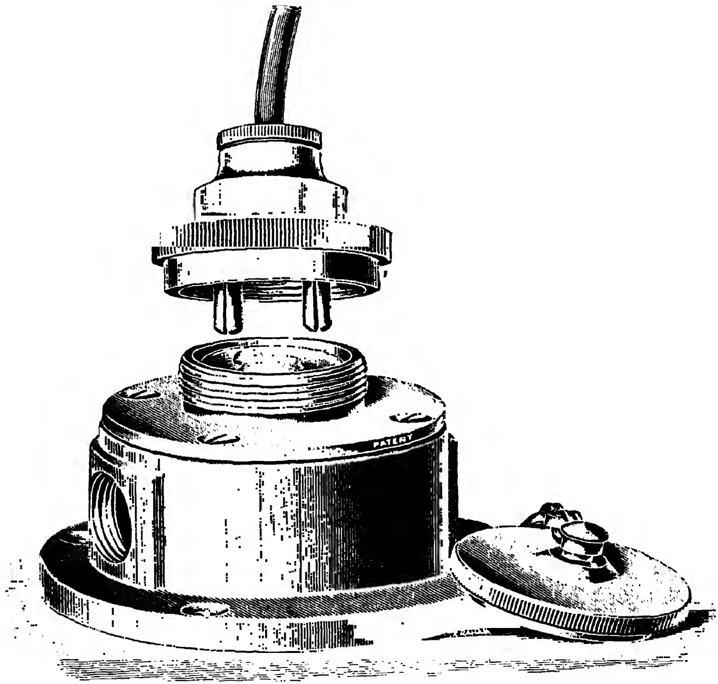


FIG. 125.—Watertight iron-clad plug.

earlier chapter. It is equally necessary that the exposed metal-work of any fitting or apparatus should also be efficiently earthed, and particularly so in the case of portable apparatus supplied from plugs. In factories which, of course, come under the Home Office Rules, such earthing is compulsory. Fig. 126 shows a three-pin watertight plug, surface type.

Four-pin Plugs.—An example of a four-pin hand-shield plug is shown in Fig. 127. Normally, the three contacts are

intended for current carrying, the fourth being the earth connection. In this case it is very suitable for use either on a three-

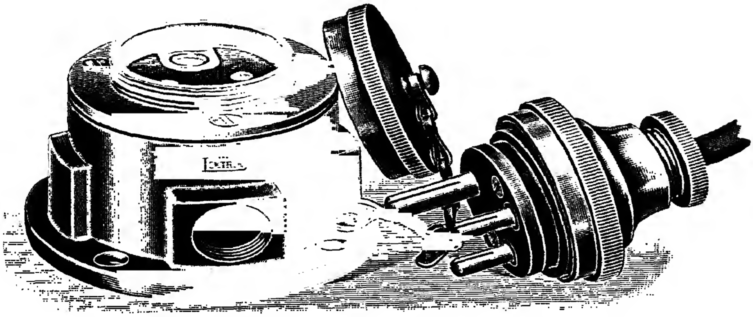


FIG. 126.—Watertight three-pin plug. (Lundberg.)

phase circuit with earth connection or a two-phase three-wire circuit with earth connection. It is likewise possible to use all the four contacts for current carrying, the fourth being made 'common' to the other three.

In the construction of these plugs, the following points should be noted:—

(1) The earthing pin should be larger in diameter (and likewise, of course, its tube), so that it is impossible for it to be inserted into either of the current carrying or 'live' contact tubes.

(2) It should be longer than the current carrying pins, so as to make the earth contact first (*i.e.*, before the other pins) and break contact last. Thus the earth contact will always be intact whenever current is flowing through the plug.

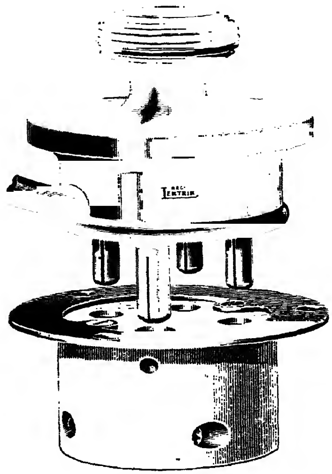


FIG. 127.—Flush pattern, four-pin plug. (Lundberg.)

(3) There must be sufficient clearance between the live pins and the earthing pin to obviate any possibility of arcing over. The contact tube of the earthing pin will, of course, be provided

with a screw terminal for receiving the earthing wire, and it is well, if possible, for this terminal to be visible.

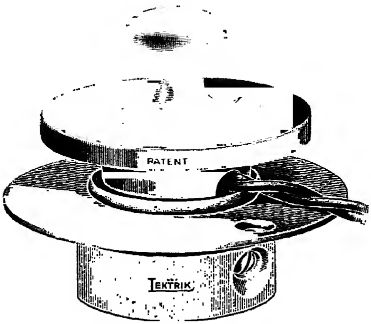


FIG. 128.—Two-pin hand-shield flush plug. (Lundberg.)

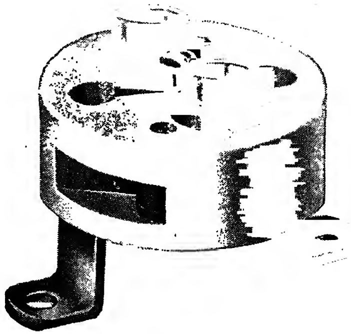


FIG. 129.—Two-pin flush plug. (Tucker.)

Patterns of Plugs.—While it is not possible, within the limits of this book, to refer to all the many patterns of plugs now being made, the following are worthy of special note :—

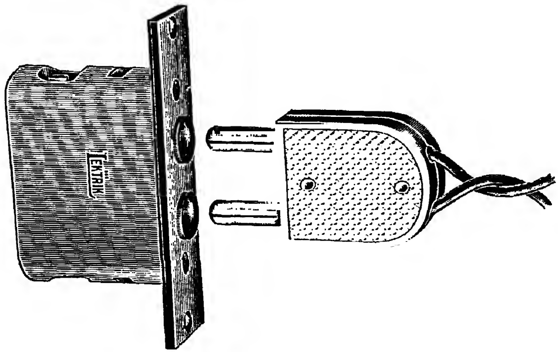


FIG. 130.—Narrow oblong two-pin plug. (Lundberg.)

Flush Plugs.—These, as their name suggests, are intended for sunk or concealed wiring. Fig. 128 shows one of the patterns made by Messrs. Lundberg, which may conveniently be used for fixing in the floor skirting. Fig. 129 shows another design

(Tucker & Co.) intended for use with a cast-iron box sunk in the wall, and fitted with the usual switch-plate mounting. It will be seen that where the plug pins pass through the plate, the

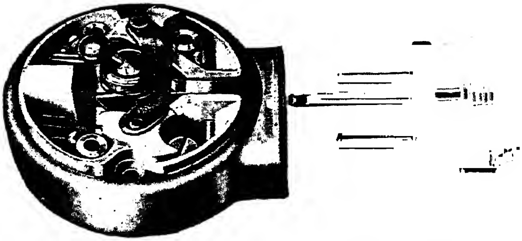


FIG. 131.—Interlocking switch plug. (Tucker.)

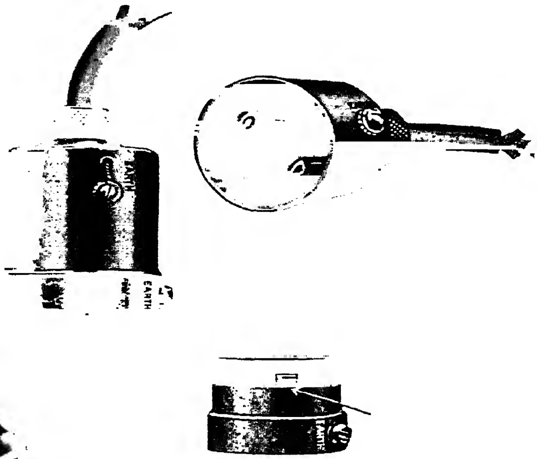


FIG. 132.—Reyrolle 'protected pin' pattern plug.

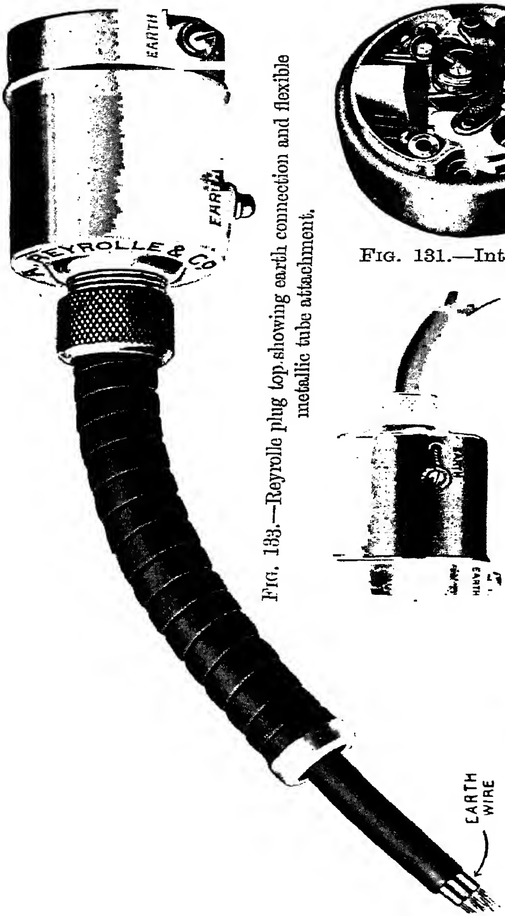


FIG. 133.—Reyrolle plug top showing earth connection and flexible metallic tube attachment.

holes are bushed with insulation, so as to shield the current carrying parts. A supporting bracket is used to fix the base to the cast-iron box, a counter-sunk screw being also used, so as to secure it to the plate.

A flush plug of the 'narrow oblong' pattern is shown in Fig. 130, this being used where only a very small space is obtainable.

Combined Switch Plugs.—An illustration of one of the

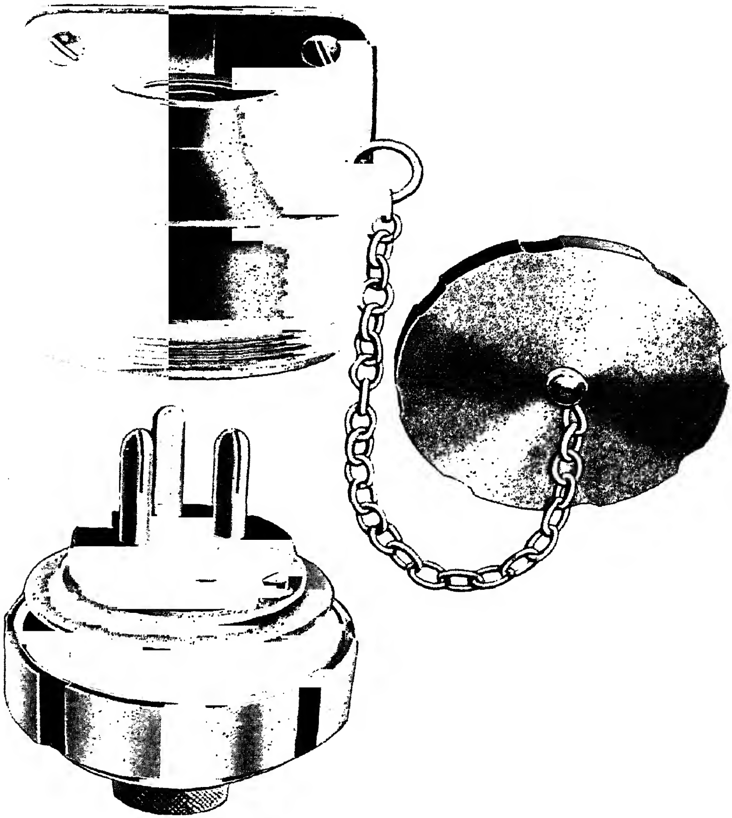


FIG. 134.—Reyrolle dockyard plug.

many patterns of these is given in Fig. 131. This is fitted with a third, but solid, pin, which locks the switch when it is in the 'on' position, and additionally acts as an earthing connection.

Plugs with Protected Pins.—Fig. 132 shows a special design of plug made by Messrs. Reyrolle. The bottom illus-

tration of the three shows the base or socket portion, the one immediately over, the two-pin top, and the one on the left, the complete article. It will be seen that the plug is contained in a metal cover, this being designed to lap over the socket, so that whether the plug be partly withdrawn or not, it is impossible to make contact with the pins, when alive. The earthing terminal is marked, and always in view, and as the top is inserted into the base, an excellent scraping contact for earthing purposes is made by the projecting springy metal tongue, seen in the bottom illustration. This design of plug is made both for domestic and for power purposes. Fig. 133 shows a larger view of this pattern of plug top, fitted with a flexible metallic tube attachment.

Dockyard Plugs.—Fig. 134 shows a pattern of plug such as would be required for heavy duty in a dockyard, or similar outdoor position. This pattern is intended to be mounted on a wall or post, and is designed for the plug to be withdrawn vertically. The socket portion is contained in a cast-iron case, a loose metal cap being screwed on when the plug portion is withdrawn.

CHAPTER XIV.

LAMP-HOLDER ADAPTORS, FIXING BLOCKS AND CONNECTORS.

Lamp-holder Adaptors.—The 'adaptor' is an appliance intended for use where it is required to make connection from an ordinary B.C. lamp-holder to another lamp-holder, or other portable apparatus, a length of flexible cord being used to connect the two. The safest pattern is the hand-shield adaptor, with a side entrance for the flexible cord, an illustration of this being given in Fig. 135. As will be noted from the illustration, this is designed for insertion in a lamp-holder in place of the lamp. It is made in hard-wood, preferably lignum vitae.

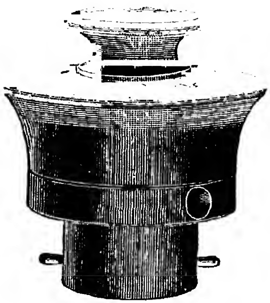


FIG. 135.—Hand-shield adaptor. (Sax.)

The ready convenience of an adaptor often leads to its misuse. It is only suitable for quite small currents; certainly not more than two amperes, and it should be controlled by a switch in an adjacent and readily accessible position.

Fixing Blocks.—Wherever a lamp switch, ceiling rose, plug or fitting is required to be fixed, it must be mounted on a hard-wood block. This should preferably be either teak, beech or walnut. Teak is desirable from its insulating and fire-resisting properties, and any hard-wood from its relative freedom from absorbing moisture.

Some of the wood blocks now being used are comparatively soft, and therefore readily take up moisture, and so tend to lower the insulation. In order that the best results may obtain, blocks, *after* being cut and drilled ready for going up in position, should be treated with one or more coats of shellac varnish, and be allowed to dry. In this way the back is as much prepared to resist the absorption of moisture as the front and edges.

Connectors.—This accessory has already been referred to in Chapter V., under metal-cased wiring systems, where its use is confined to jointing up conductors. It does, however, find another use for joining the flexible cord of fittings to the circuit wires. Under the Regulations of the Institution of Electrical Engineers,[1] this is the only method permissible, any form of twisted joint between flexible cord and hard wire being most undesirable.

Connectors are obtainable in sizes sufficiently small to be contained behind the ceiling plate of any pendant fitting, or behind any pattern of wall bracket. They should be made of English vitreous china, and have solid brass terminals. The cheese-headed screws should be flat-ended, and have well-cut threads, and the whole of the metal parts should be well shrouded in the china.

[1] Regulation 93 B.

CHAPTER XV.

FUSES AND DISTRIBUTION BOARDS.

A FUSE or cut-out is a piece of wire or foil which has been selected, of such a metal and of such section and length that it will melt, and therefore interrupt the circuit in which it is placed, should the current reach a limit which would be dangerous to the conductors, or to any apparatus connected to them. It may therefore be regarded as the 'safety valve' or protective device of the electrical circuit.

For fuses carrying fairly small currents, the wire used is commonly a tin-lead alloy. For larger currents, a wire of copper, preferably tinned, is more suitable. The reason for this is that copper, being a metal of high conductivity, the size of the fuse wire would be inconveniently small for small currents. With regard to a tin-lead alloy, this, whilst being eminently suitable for small currents, would, owing to its high resistance, necessitate a wire of considerable diameter, if it were used in circuits carrying large currents, and when a fuse wire of large diameter melts, it is liable to scatter a considerable quantity of molten metal—which is very undesirable.

From the accompanying table will be seen the approximate current necessary to fuse wires of a given size in copper and in tin-lead alloy. Any such table must be regarded as essentially approximate, owing to the fact that there are many points which go to influence the fusing current of a wire of given material and diameter. Amongst these points may be mentioned: (1) The length of the fuse wire. (2) Its position—(whether vertical or horizontal). (3) The type of china carrier in or on which it is mounted. (4) Whether open to the air or enclosed in asbestos, or other material. Naturally, fuses which are enclosed are, other circumstances being equal, quicker in action than open ones.

Where accuracy is required, the fusing current for a given fuse wire is best ascertained by actual experiment with the particular fuse carrier with which it is to be used.

Tin-lead Alloy.		Tinned Copper.	
Diameter of Wire (In.).	Approximate Fusing Current.	Diameter of Wire. (In.)	Approximate Fusing Current.
·0076	1·09	·0036	2·2
·0124	2·26	·0068	5·7
·018	3·97	·0084	7·9
·022	5·4	·010	10·2
·028	7·7	·0124	14·1
·036	11·2	·018	25·0
—	—	·036	70·0
—	—	·048	100·0

Fusing Currents Permissible.—The correct size for a fuse must, naturally, be governed by the current carrying capacity of the smallest conductor which it is intended to protect. It should, in any case, be arranged to 'blow' with an over-load of not more than 100 °/ₒ of the rating of such conductor. For final sub-circuits, however, it is permissible, under the Regulations of the Institution of Electrical Engineers, to provide that no fuse need be smaller than one blowing at a current of seven amperes.

Distribution Boards.—Reference was made to this subject in Chapter VIII. of Section II. Types and details of construction will now be dealt with.

All distribution boards are either wood-cased or iron-clad. The former is in very general use for ordinary lighting, and also for small power work, and provides satisfactory results for positions where watertightness is not essential, and where a low initial cost of the installation is imperative. Both types are obtainable with the fuse ways mounted on a panel of black china or on one of enamelled slate. Alternatively, each way may be mounted on a separate slab of china, this latter arrangement obviously providing for a higher insulation resistance.

The following are points which it is desirable to obtain in any distribution board:—

(1) The positive and negative sections to be isolated from one another by means of an insulating division wall, which may be of slate, marble or china, and which must be securely fixed in position.

(2) Sweating sockets to be provided for connecting the cables

with the bus-bars, such sockets being preferably on the front of the board.

(3) Conducting metal-work: The bus-bars should be of copper and the fuse contacts should be of either copper or phosphor bronze. The sections and areas of both the bus-bars and the contacts should provide for a low-current density; in the latter case, this should not exceed 300 amperes per square inch, although, in the bus-bars, it may be safely taken up to 1 000.

(4) The length of break of the fuse for the ordinary patterns

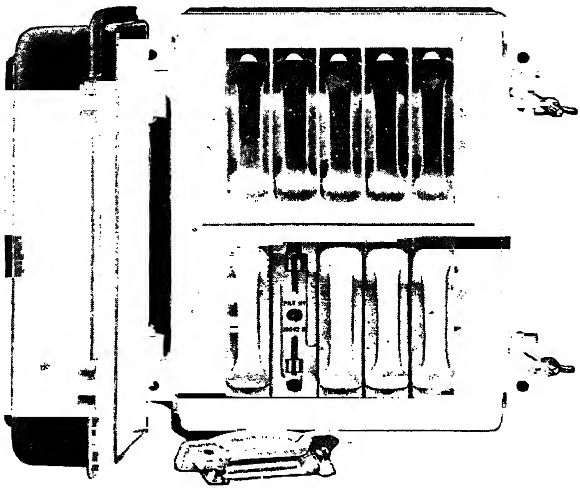


FIG. 136.—Home Office surface type iron-clad distribution board. (Tucker.)

of fuse carrier should not be less than 3 inches. For heavy duty, however, this requires to be considerably increased.

(5) Ample spacing should be provided between the several fuse-ways, so that any fuse carrier, whether 'finger-grip' or 'hand-grip,' may be safely and quickly removed or replaced.

(6) Wood-cased distribution boards should have their glass fronts clear of all live metal-work by not less than 1 inch.

(7) Metal-cased distribution boards must be designed with sufficient spacing between the parts, that there is no possibility of arcing taking place between the live parts and the case; which case will, of course, be earthed.

(8) All nuts used in the fixing of the current carrying parts to be lock-nutted.

(9) Provision should be made that each fuse-way can be numbered, preferably inside the case. A 'key' or table showing the circuit or circuits fed by each way will then be provided near to the board for ready reference.

Many distribution boards, both teak-cased and also iron-clad, are now described as 'Home Office' type. In these, the main intent is a maximum of safety to the user. Two such types of board are illustrated in Figs. 136 and 137. It will be noticed that all live metal-work is completely enclosed, or shrouded, in china, the projecting walls of the base and the wide flange of the carrier preventing any accidental contact with live metal, when either withdrawing or inserting the fuse carrier. The same type of board, as shown in Fig. 136, is also made in a teak case, for ordinary surface work. Of equal importance as danger from shock is the risk of fire. Hence the necessity for due regard to item No. 7 in the list of points given.

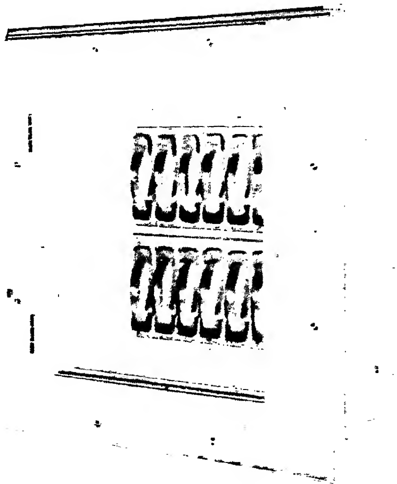


FIG. 137.—Home Office iron-clad distribution board, sunk type. (Tucker.)

Sizes of Distribution Board.—The ratings adopted by most manufacturers are: 5, 10, 15, 30 and 60 amperes per way.

Patterns of Fuse Carriers.—In Figs. 138, 139, 140 and 141 are shown some patterns of fuse carrier adopted by the General Electric Co. Ltd. As already pointed out in this chapter, the design of the carrier is a matter of considerable importance. In one design which is often seen, the fuse wire lies in an open groove on the top of the china. In others of the tubular pattern, an inspection hole is left in the top of the china. Both of these would seem to leave much to be desired, if maximum safety to the user is to be provided, as it is readily conceivable that, if such carriers be replaced on a live

circuit from which the fault has not been cleared, the operator has every chance of receiving injury to his hand or face.

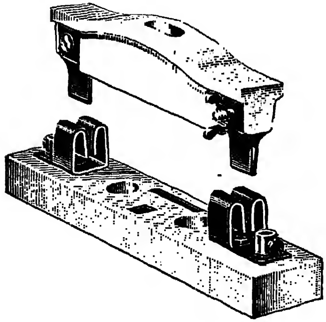


FIG. 138.—Under-channel type.

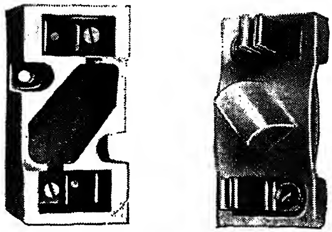


FIG. 139.

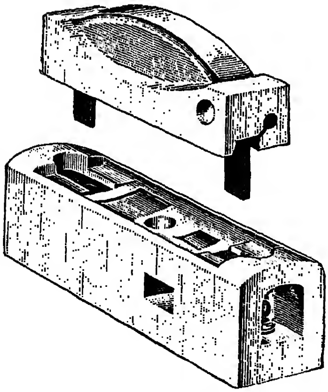


FIG. 140.

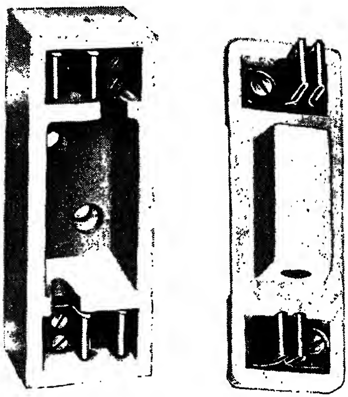


FIG. 141.

FIGS. 138-141.—Fuse carriers and bases. (G.E.C.)

Positions for Distribution Boards.—The position for fixing a distribution board, particularly if this be a wood-cased one, should be carefully selected. Apart from any electrical consideration, the position chosen should be dry, clean and well-lighted, and provide ready access without the use of ladders or steps.

CHAPTER XVI.

MAIN FUSES AND SWITCHES.

THESE are now entirely of the iron-clad pattern, and are frequently combined, so as to form one piece of apparatus. Alternatively, they may be installed as separate units. In the simplest case, that of an ordinary two-wire circuit, the fuses will be single pole, although, of course, the two poles of the switch will be mechanically linked together, so as to make and break simultaneously.

An example of an iron-clad and watertight fuse suitable for lighting, or power circuits up to 500 volts is given in Fig. 142, its component parts being shown in the succeeding illustrations, Figs. 143, 144 and 145. A miniature pattern of this, suitable for circuits up to 250 volts, and carrying up to 15 amperes of current, is shown in Fig. 146, its component parts being seen in Fig. 147, this latter pattern being not necessarily watertight.

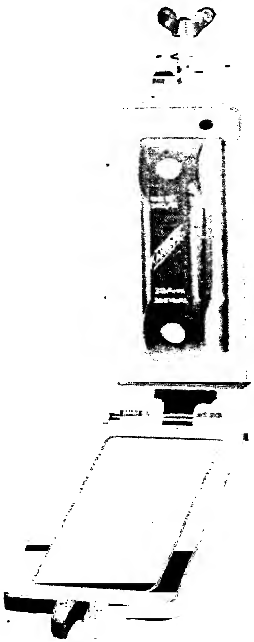


FIG. 142.—Iron-clad watertight S.P. fuse. (Midland Electric Manufacturing Company.)

In selecting an iron-clad fuse, it is desirable to obtain, if possible, the following points :—

(1) The design of the fuse unit, that is, the carrier and the base, to be such that it will be non-arcing on a dead short-circuit fault, and that its parts shall be (as in all the Home Office patterns) sufficiently shrouded in china to protect the user's hand.

(2) The base should be independently fixed to the iron box, so that this latter is, likewise, independently fixed to the wall or mounting.

(3) As little as possible of the under surface of the base should be in contact with the interior of the iron box. Frequently, some insulating packing, such as mica, is interposed between the two.


FIG. 143.

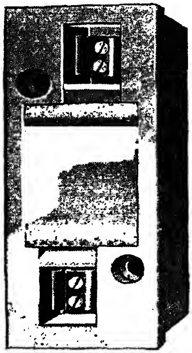


FIG. 144.

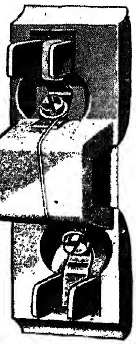


FIG. 145.

FIGS. 143-145.—Parts of Midland Electric Co.'s fuse unit.

(4) Where the cable entries are bushed, these bushings should be of ample size to receive the cable, and should be of a design that does not drop out. Where, however, the metal conduit is taken right into the iron box, sufficient room should be provided to allow

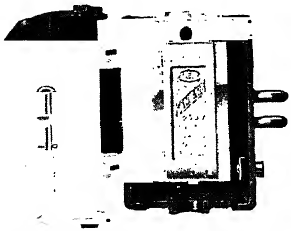


FIG. 146.—Miniature pattern of iron-clad fuse. (M.E.M. Co.)

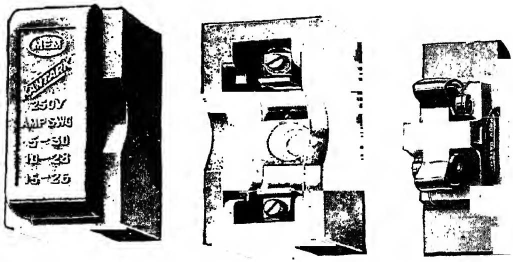


FIG. 147.—Part of fuse unit, miniature pattern. (M.E.M. Co.)

of a lock-nut and washer inside, similar provision being made, of course, outside.

(5) Wherever possible, connection with the conductors should be by sweating sockets. Many designs allow, however, only for grub screw connections. In this latter case, it is desirable that the

ends of stranded conductors should first be made solid by soldering, before insertion into the terminal.

An illustration of a D.P. iron-clad, watertight switch is given in Fig. 148, a triple-pole switch of the same general design, but combined with 3 S.P. fuses being shown in Fig. 149.

The following are the points which it is desirable to obtain in this class of switch gear:—

(1) The switch should be both quick-make and break, and it should provide for a double break simultaneously on each pole.

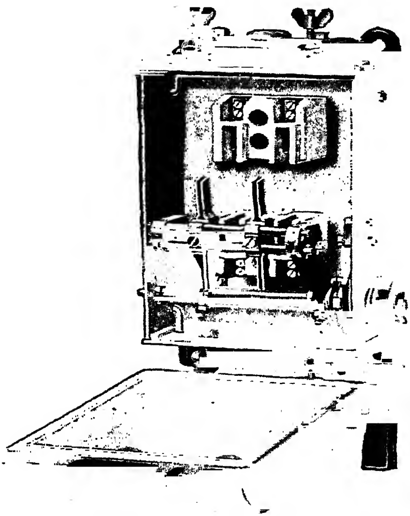


Fig. 148.—D.P. watertight switch. (M.E.M. Co.)

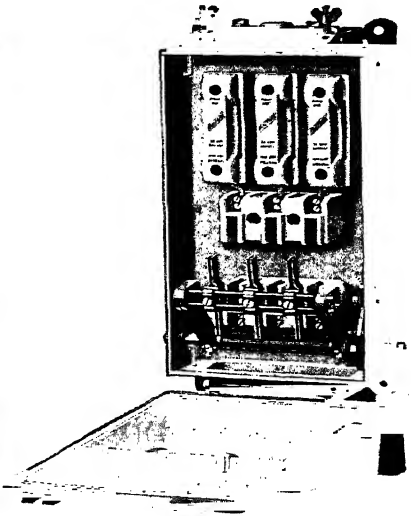


Fig. 149.—Triple-pole switch and fuses, interlocking pattern. (M.E.M. Co.)

(2) Blades and contacts should be of copper, the section of the latter providing for a current density not exceeding 90 amperes per square inch of surface contact.

(3) The switch contacts should be as fully shrouded in china as possible, so as to minimise the possibility of arcing to the iron case.

(4) Any spring employed in actuating the switch movement should be copper-plated, to prevent rusting.

(5) The entrance for the cables should be as direct and as roomy as possible, to facilitate wiring.

(6) The operating handle, which will be at the side of the case

will be interlocking, so that the latter cannot be opened whilst the switch is in the 'on' position.

Additionally, the points numbered 3, 4 and 5, applying to iron-clad fuses, may also be taken as applying with equal force to iron-clad switch gear.

Cable Sockets.—In order that the end of a conductor may be properly connected to its circuit terminal, such as that of a main fuse or switch, distribution board bus-bar, meter, etc., sweating sockets or 'thimbles' are required on all but the smallest sizes.

Under Regulation 92 of the Institution of Electrical Engineers, all conductors larger than ·04 sq. inch in area (19 / ·052 inches), should be provided with sweating sockets, although it is also recommended in the Regulation that smaller sizes than this should likewise have them.

Most cable sockets are made in cast brass, although some manufacturers prefer to forge them out of seamless copper tube. It is essential that the two faces of the socket which make contact with the bolt or stud, should present a perfectly true surface, otherwise the full area of contact will not be obtained, and usually it is necessary to surface them by hand-filing before use, in order to meet this point. The size of the socket must always be sufficient to receive *all* the strands of the conductor simultaneously.

The sweating up and insulating of a cable socket should be carried out as follows:—

(1) If not already tinned, the socket should first be cleaned and then well tinned inside, this being done by heating in a blow-lamp and the use of a little resin and fine blow-pipe solder.

(2) The cable end should be stripped of its insulation for say half an inch more than the length necessary, to enable it to enter and properly fill the socket, its strands being cleaned and tightened up.

(3) The socket, having been thoroughly heated, the bared cable-end is inserted into it, and the socket again heated with the blow-lamp whilst it is being filled up solid with solder, a little resin being used, to assist in the operation. The solder should run up into the strands of the cable.

(4) The socket having been allowed to become thoroughly cool, the insulation which has been damaged by heat will be cut away down to the actual strands of the conductor, the tape and braid being removed for at least another inch beyond.

(5) Pure Para rubber strip should then be lapped tightly round

the exposed vulcanised rubber up to the actual socket, care being taken that this lapping starts on the vulcanised rubber, and not on the tape or braid. The lappings will be sufficient to make the finished diameter about equal to that of the socket, and it is well to take say one lapping of the rubber strip over the metal of the socket, when putting on the last layer. It is well also to run on one or two layers of waterproof black tape over the rubber, care being taken that this starts on the braid of the cable, but is kept well back from the live metal of the socket.

Insulating Materials Used in Installation Work.—*Pure Rubber Strip or Tape.*—This material is essential for insulating purposes wherever V.I.R. conductors are used, one example being the finishing off of a cable socket. It is supplied in widths from ½ to 1 inch. It should be used whilst new, as old rubber strip is liable to become brittle. When being applied, it should be well stretched and each turn lapped by say half its width over the previous one.

Black Tapes.—These may be either 'proofed' tapes, or the kind usually known as 'sticky' tape. The former, which is the superior article, consists of a fine cotton cambric, proofed with rubber compound either on one or both sides, and in the latter case is known as 'double-proofed tape.' It is excellent for lapping over any rubber insulation to form the finishing layer. 'Sticky' tape, being considerably cheaper than 'proofed' tape, is much more frequently used by contractors. It consists of a cotton fabric impregnated with an adhesive waterproof compound. It should be very tenacious, clean to handle, and free from any substances likely to be injurious to rubber.

Plain Selvedge Tape.—This is a stout, closely woven cotton tape, suitable for insulating joints in paper insulated conductors, or joints between paper and V.I.R. conductors, when these are contained in joint boxes. This tape should be thoroughly boiled before use, in an insulating compound, such as resin oil, and then lapped straight away on to the joint.

SECTION IV.

THE TESTING OF A COMPLETED INSTALLATION.

CHAPTER XVII.

On the completion of an installation, it is essential that tests should be made, in order that its condition may be ascertained.

Tests of the Insulation Resistance.—These are to show the value of the insulation resistance as existing between the wiring, fittings and accessories, in fact, any current carrying part and

Fig. 150.—The 'Megger' insulation testing set.

earth, or, alternatively, between the two conductors of the system which are of opposite polarity or opposite phase.

Measuring Instruments.—Probably the best-known instrument for insulating testing is Evershed's 'Megger.' Electrically, it consists of two parts, the ohmmeter and the generator, which are conveniently arranged in one case. The former indicates on the dial of the instrument the value of the insulation resistance under test, the latter providing the necessary pressure for testing.

Fig. 150 shows a general view of the instrument. It is obtainable in three patterns: the ordinary or 'variable pressure' set, the 'constant pressure' low-range set, and the 'constant pressure' high-range set. The first mentioned is quite suitable for testing wiring installations which do not possess any appreciable electrostatic capacity. The testing pressures for which this pattern is made are: 100, 250 and 500 volts.

A constant pressure set is, however, essential wherever the installation comprises a considerable amount of wiring in metal conduit, lead-covered conductors, or underground mains, etc., and thus presents considerable capacity. By means of a special clutch, the armature speed, and therefore the voltage of the generator is maintained constant during the period of the test. After the initial charging of the circuit to the testing voltage, no further 'capacity' currents will occur, and therefore a steady reading is obtainable. These constant pressure sets are obtainable for the following pressures and ranges :—

Low Range Sets.		High Range Sets.	
Constant E.M.F. in Volts.	Range in Megohms.	Constant E.M.F. in Volts.	Range in Megohms.
100	0 to 10	500	2 to 1 000
250	0 ,, 20	1 000	4 ,, 2 000
500	0 ,, 100	1 000	4 ,, 5 000
1 000	0 ,, 200	2 500	4 ,, 10 000
2 500	0 ,, 1 000	—	—

Method of taking a Test.—If the installation has already been used, care must be taken to see that it is first disconnected from the public or other supply mains.

The instrument selected must give a testing pressure at least *double the working pressure.*

To measure the insulation resistance between both poles and earth: Choose the necessary length of V.I.R. conductor for connecting from the 'Line' terminal of the testing set to the terminals of the main switch, this conductor being always one in sound condition. (Bell wire is *not* suitable for this purpose.) The two terminals of the switch will be temporarily connected together. From the 'Earth' terminal of the testing set a piece of

wire will be taken direct to something which forms a good connection with the general mass of the earth, as, for instance, a live water main.

The handle of the testing set will then be turned, somewhat cautiously at first, and the value of the insulation resistance in megohms read off on the dial provided. Fig. 151 shows the connections referred to.

For the above test, all lamps should be *in*, all fuses *in*, and all switches *on*.

To measure the insulation resistance between the two poles of the circuit, or indeed between any two conductors: choose two pieces of V.I.R. conductor in sound condition, these being used for connecting from the two poles (or conductors) under test, to

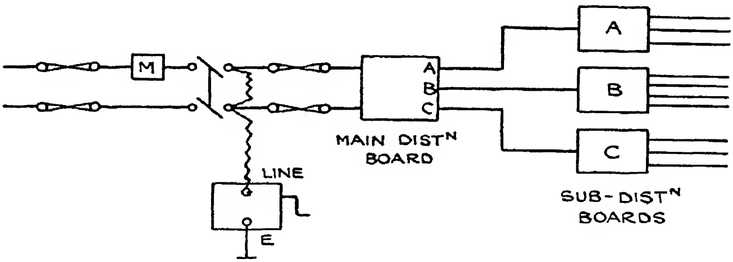


FIG. 151.—Connections for insulation testing.

the 'Line' and the 'Earth' terminal respectively, of the testing set, and proceed as previously.

For this test, all switches should be *on*, all fuses *in*, and all lamps or other current-consuming devices *out*. It is obviously impossible to take a test of insulation resistance between two conductors if these are connected together through a lamp, or any other current-consuming apparatus. Some testing engineers suggest that if the lamps or other apparatus cannot be removed from the circuit—that it is sufficient to open the single pole switches. This, however, does not meet the case, as the testing pressure is then merely applied across the switch bases.

In testing the insulation resistance of circuits containing multiple way switches, care must be taken that *all* the conductors between the switches or between lamps or other apparatus are

included in the test. A convenient way of ensuring this would be to short-circuit the several terminals of each of such switches.

Standard of Insulation Resistance.—The standard of insulation resistance which is now usually accepted, is that adopted in the Regulations of the Institution of Electrical Engineers.[1] By this, the insulation resistance as measured between earth, and the whole system shall not be less in megohms than 25 divided by the number of points, a point being the end of the wiring for feeding one or more lamps, or other current-consuming device. Thus, an installation comprising 42 points should show an insulation resistance of: $\frac{25}{42} = \cdot 59$ megohm, or one of 150 points, say ·16 megohm. The Regulations further provide that any installation need not necessarily show a greater insulation resistance than 1 megohm.

With regard to the necessary insulation resistance of motors, generators, heaters, cookers, motor starters, speed regulators, etc., or any other electrical apparatus, this should be in accordance with the standard provided for in the appropriate British Engineering Standard Specification, and where no such specification exists, it should not be less than half a megohm, as measured between the current carrying parts and the frame or case.

Given ordinary conditions in the interior of a building, any installation, if reasonably well done, should show *at least* the figure of insulation resistance, as provided for by the Institution of Electrical Engineers' Regulations.

Points Influencing Insulation Resistance.—When making tests, many points will be found to influence the value of the insulation resistance as obtained. Amongst these may be mentioned (*a*) Weather conditions. With a humid atmosphere, the condensation of moisture on the china parts of the many accessories using this material will inevitably cause surface leakage.

(*b*) Dryness, or otherwise, of the building. Wiring work carried out in new buildings, whilst they are in course of erection, cannot be expected to show high insulation resistance, the unavoidable dampness setting up surface leakage, as in (*a*) over the china surfaces. The ends of the conductors will also be the subject of surface leakage both in (*a*) and in (*b*).

(*c*) The proper cutting back or trimming of the tape and the braid of the V.I.R. conductors, where this might otherwise touch

[1] Ninth Edition, May, 1927, Regulation No. 127.

china or other hygroscopic surfaces, will, in the aggregate, affect appreciably the insulation test obtained.

(*d*) Where the work is carried out in steel conduit, the crowding together, or otherwise of the conductors within a given size of conduit, will be found to affect the insulation test obtained.

Relative Insulation Resistance in a D.C. System.—Separate tests of the two poles of an ordinary 2-wire system may disclose results which are widely different. In a new installation which has not been put into service, the red or positive conductor will probably show a lower insulation resistance to earth than the black, owing to (1) its very much greater length, due to its feeding the single pole switches, and (2) the connection to this conductor of the switches themselves. A subsequent test, taken after the installation has been in service some considerable time, may show the order of insulation resistance of the two poles to be reversed, the black or negative now being the lower. The explanation of this is to be found in the action known as 'electrical osmosis.' By this, any trace of moisture present in the system, is, by the action of the leakage current, transferred from the positive to the negative side of the system. Obviously, an alternating current system does not suffer in this way, owing to the fact that the current is experiencing very rapid reversals of direction round the circuit.[1]

Periodical Tests.—The value of making a test of the insulation resistance, periodically, say every six months or so, cannot be too strongly emphasised. It is only by such a method, and the keeping of careful records, that any gradual deterioration can be noticed, and therefore rectified. Unnoticed, a gradual deterioration means ultimate break-down.

A good insulation test, by itself, and without other knowledge of the installation, must not be taken as necessarily indicating a perfect job. An insulation test cannot show many features of bad workmanship or inferior materials. Cheap, foreign-made V.I.R. conductors do not necessarily cause a low *initial* test of the installation. The existence of bare wires which are nearly touching and only need a little vibration to bring them into contact, and numerous other faults, cannot be disclosed by any test, but only by actual inspection.

[1] Reference might well be made to a paper read by Mr. E. Ambrose before the Junior Institution of Engineers. (*Journal J.I.E.*, Vol. 37, Part 9, June, 1927.)

Faults in Insulation Resistance.—The faults commonly met with when taking tests for insulation resistance, are (*a*) dead earths, and (*b*) lowness of resistance, either partial or general. The former will, of course, be due to a direct contact between a current carrying part of the installation and some earthed material, such as metal conduit or the metal sheathing of a metal-cased wire system. With regard to a lowness of insulation resistance, where this is general to the whole system, surface leakage would probably be the cause. In new buildings, where the wiring work is carried out whilst the building work is in progress, this defect is very commonly found, and may be traced to the condensation of moisture in the innumerable china parts which have to be used, as well as to creeping over the ends of the tape and braid of the V.I.R. conductors. If the lowness of insulation resistance is partial only, it will probably be traceable to defects in the trims and connections, or to the presence of local moisture.

Faults of the above description which are 'intermittent' only, are obviously due to a contact, intermittent itself, which is made and broken by vibration.

The localising of faults in insulation resistance is usually a fairly simple matter. In reference to Fig. 151; (1) break the line connection and test from each pole separately. This will show if the fault is common to both poles, or to one only, and, if the latter, then which. This point having been settled, (2) attention should be given to the main distribution board. Withdraw fuses for subboard A, and repeat test. If the fault be still present, replace A's fuses and withdraw B's. A subsequent test will then show if the fault be in connection with sub-board B or sub-board C. (3) The fault having been localised to the final sub-board—it remains to be traced from this final sub-board, that is, in the 'point-wiring.' The several fuses of the final sub-board will therefore be withdrawn in succession, the test being repeated each time, until the faulty one of the final sub-circuits is located. After this, visual inspection is directed to those places, accessories and fittings, whether for lighting or power, where experience suggests that faults most commonly occur; this being by far the most rapid method of procedure.

Switch Polarity.—It is sometimes required to test the polarity of the single-pole switches, in order to prove that they are in every case connected to the same pole of the system. This test is readily carried out by means of a lamp, the lamp-holder being wired with

the necessary length of flexible cord. If the two ends of the cord are separated and used to make contact with any two selected switches simultaneously, the lamp will, of course, light up, should these two switches be of opposite polarity.

Volt-drop Test.—Where the permissible drop in volts between any two points in the circuit has been specified, this may be checked

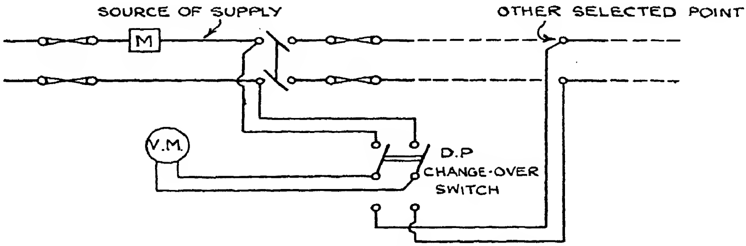


Fig. 152.—Connections for a volt-drop test.

by means of an appropriate volt-meter and a double-pole change-over switch, the connections being made as in Fig. 152. It is assured, of course, that the load on the circuit and its supply voltage remain constant while the test is being made. An alternative method would be to employ two volt-meters, being one at each end of the circuit, and two observers who will, of course, make their readings simultaneously.

SECTION V.

THE PLANNING OF A LIGHTING INSTALLATION.

CHAPTER XVIII.

IN setting out to design an installation for any given building the first step is to prepare a Schedule of Lighting. This should include the following essential particulars as given in the specimen schedule hereunder :—

Schedule of Lighting.

1.	2.	3.	4.	5.	6.	7.	8.	9.
No.	Room.	No. of Points.	Position of Points.	No. of Lamps.	Watts per Lamp.	Switches.	Fittings.	No.

Totals :—

Such a schedule can be prepared from an inspection of the building, or if this be not yet built, then from the Architect's plans. The columns may vary slightly with different jobs, and in cases where every point is a single lamp point column 5 can be dispensed with.

Points to Observe for Correct Lighting.—The choice of the number, size and positions of the lamps required to efficiently illuminate the several rooms of a house or other building is but part of the vast subject of Illuminating Engineering. Although it is not possible to give an exhaustive treatment of this subject within the limits of this book, the following points will be of service to those who desire to arrange any given installation as efficiently and economically as possible :—

(1) When deciding the position for any lamp, care must be taken that the light does not come directly in the line of vision, as the effect of this on the eye is to prevent a person from properly seeing adjacent objects. This involves the question of the correct height.

(2) The illumination provided must be sufficient though not excessive. The degree of illumination which it is necessary to obtain on the 'working surface' will vary according to the nature of the work to be done. For reading purposes, for instance, an intensity of illumination of from two- to three-foot candles is often adopted, whereas in passages, corridors and similar positions one-foot candle would amply suffice for safety. In many of our railway station booking halls the illumination provided for the passengers is often very considerably less than this figure.

(3) When the illumination provided is mainly *local*, care should be taken to see that a sufficient amount of *general* illumination is also provided in order that the rest of the room is not left in comparative darkness.

(4) For the *general* lighting of a room, workshop or any other interior the effect of *colour* on the reflection obtained must be considered. White or light coloured surfaces may reflect at least 50 °/₀ of the light falling upon them, whereas such colours as terra-cotta or peacock-blue are extremely absorbent.

(5) Illumination cannot be judged by *looking at the lamp*. It must be *measured*. A brilliant lamp in an unsuitable fitting may produce 'glare' and yet give a poor illumination on the surface where it is required, whilst a lamp of smaller wattage in a correctly chosen reflector may produce a higher figure of illumination where required.

(6) In most cases it is necessary to consider, not only the size

or wattage of the lamp to be used but also the reflector or other fitting in which it is to be housed, together with the height above the surface at which it is to be mounted, in order that a correct scheme of illumination may be obtained. In certain buildings, however, which are not of a strictly industrial character, the decorative design of the fitting may have to take precedence over all other points.

The Choice of Lamps—Sizes and Types.—For house lighting purposes the sizes of lamps most commonly required are the 20, 40 and 60 watt. The 20 watt will be restricted to minor positions such as cellars, larder and lavatories, etc. For bedrooms the 40-watt size is essential, and in living rooms either 40 or 60. These two latter may be had either in the vacuum or the gas-fitted pattern, and for bowl fittings, which really form a semi-direct system of lighting, the gas-filled lamp becomes essential. Lamps of 100 watts and over are mostly employed in industrial or commercial establishments and in shops and public buildings.

Fittings.—These may be either those that are mainly decorative in character, such as pendants, electroliers, brackets, etc., as used for private residences and certain public buildings, or they may consist of scientifically designed reflectors which either focus or spread the light over a known area when mounted at a given height. Of these, two patterns only need be mentioned; those made of clear prismatic glass-ware by the Holophane Company and those made in pressed steel by the Benjamin Electric Company, Limited. Each of these can be used with flexible cord or other pendants, or be mounted with a back-plate lamp-holder direct on to the ceiling. Holophane reflectors are of three types, the 'extensive' or E-Type, the 'intensive' or I-Type, and the 'focussing' or F-Type. The E-Type is used where a wide distribution is required, and the F where concentration is required over a comparatively limited area. The intensive type is midway between these two. Each reflector is designed for use with a lamp or lamps of given wattage, and for these only is it suitable, as the position of the lamp in the reflector appreciably affects the light distribution obtained. The Benjamin reflectors are made in two types, the 'extensive' for wide distribution and the 'intensive' for concentrated illumination over a small area. These reflectors must also be used with appropriate lamps for their respective sizes.

Allocation of Lighting Points.—With regard to the proper allocation of the different lighting points to the several circuits of the distribution board this can only be settled after a careful survey of the circumstances of each particular job. The general principles which should be followed, will, however, be found set out in Chapter VIII. of Section II. of this book.

SECTION VI.

ELECTRIC HEATING AND COOKING.

CHAPTER XIX.

THE installation of electric heating and cooking will follow very much upon the same general lines as already laid down in this book for electric lighting. It will, however, be noted that in heating and cooking circuits the currents dealt with are usually very much greater than those required for ordinary lighting, and that as those are mostly supplied at the higher pressures (200 to 250 volts) greater care is necessary, particularly in the choice of accessories and materials. Usually, as a much lower rate is charged where energy is required for heating purposes, a separate wiring system for this becomes necessary.

Conductors.—For circuit wiring V.I.R. conductors will generally be used, of the same type as in lighting installations. Where flexible cords are employed—as in all portable heating apparatus these should be chosen of the circular braided pattern. In special cases it may be necessary to employ cord which is asbestos braided in order to ensure its being as fire resisting as possible. The section of all conductors will be chosen in accordance with (*a*) the maximum permissible current and (*b*) the permissible voltage drop. With regard to the former the section should be chosen liberally so that there is a margin of safety in the event of the heating apparatus being replaced by the owner by one of somewhat larger size as may sometimes occur in the case of small electric fires. It must also be remembered that the initial current of the fire will exceed the 'running' current or current when hot. Now with regard to the latter this should be kept as low as possible, as otherwise the full heating effect of the apparatus cannot be expected. Whilst always important, it is especially so in the case of electric cooking circuits where it is advisable to keep to a maximum of say not more than 2 volts at full load. Flexible cords will generally

require to be of the three-core pattern in order that due provision may be made for earthing the exposed metal work of the heating or cooking apparatus used. The cord used should be of the 'finished circular' pattern, ordinary 'twisted' flexible cord being liable to kinking.

Wiring Systems.—Of the several systems described in Section II. of this book the screwed conduit system will obviously offer the maximum protection to the conductors, and this system is generally adopted wherever the heating or cooking requirements are of appreciable size. In certain positions, such as bathrooms and kitchens, etc., care must be taken to avoid condensation taking place in the conduit, where this is run on the surface.

Circuits.—Heating circuits, will, as in the case of lighting, radiate from a distribution board or boards which will be controlled by main switches and fuses in the usual way.

The arrangement of the circuits and the number of distribution board ways which shall be provided to supply them must be settled according to the size, disposition and general character of the installation. For instance, circuits feeding electric sealing-wax heaters taking 70 to 150 watts each, or electric glue-pots taking 250 to 350 watts each may, if necessary, be grouped so that 2 or 3 such appliances form one circuit at the distribution board, whereas electric fires taking say 1 kilowatt or more each would obviously be arranged so that each one formed a separate circuit, and likewise of course any appliance whose consumption was greater. The main point to be considered is that of convenience—so that the blowing of a fuse shall put out of action only the minimum number of appliances.

Heating installations of an appreciable size, say 3 kilowatts or over, will require to be arranged so as to form two main circuits for connection across the three-wire public service where this is a D.C. one.

Where the supply is by A.C. either two- or three-phase the load will likewise be required to be split up into 2 or 3 main circuits, so that it may be balanced across the phases.

In the case of a large electric cooker which may often take up to 10 kilowatts it is customary to balance its several 'loadings' or parts across the supply circuit, the manufacturers often making provision for this in the switch-board supplied with the cooker. An example of this is shown in Figs. 153 and 154 which give re-

spectively the front and the back views of a cooker switch-board 'split' for balancing across the outers or the phases of the supply.

Heating Accessories.—All accessories should be of as robust and solid construction as possible. Though desirable in a lighting installation this point is even more imperative where heating apparatus is concerned. For electric cookers and also for many of the larger sizes of electric fires, the rotary type of switch is much

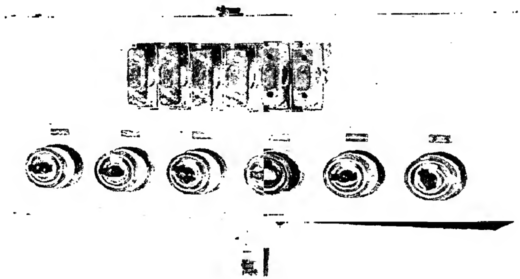


FIG. 153.—Front view of split switch-board. (Jackson Electric Stove Co.)

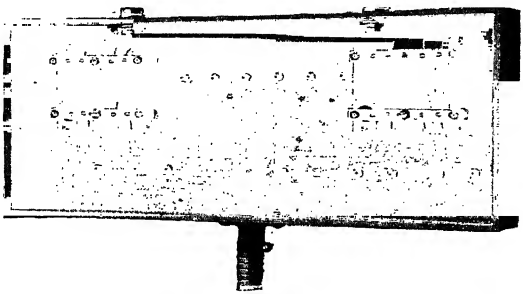


FIG. 154.—Back view of split switch-board. (Jackson Electric Stove Co.)

to be preferred to the tumbler type on account of its better contact surface.

With regard to plugs it is necessary that the pins should be thoroughly firm fitting in their sockets, as any slackness therein means that part only of the contact surface is making contact with the consequent risk of heating and arcing if not actual fusing. The plug top must be so designed that it firmly grips the outer covering of the flexible cord whether this be whipcord braided,

metal-sheathed, or the C.T.S. pattern. All plugs should preferably be of the three-pin or earthing pattern and interlocked with their switches.

Earthing.—The necessity of the earthing of all the exposed metal-work of heating and cooking apparatus cannot be too strongly urged, and the Regulations of the Institution of Electrical Engineers make this very clear.[1] Electric fires or radiators of any kind where used in bathrooms, etc., and likewise electric cooking apparatus which is used in kitchens or sculleries—should receive special care as regards earthing and without any regard to the voltage of the supply circuit. The notes on this subject which have been given in Chapter IV. of Section II. should be carefully followed.

[1] Regulations: 96 and 123 C (9th Edition).

APPENDIX.

These Tables are reproduced by the kind permission of the Institution of Electrical Engineers.

Table I.—*Dimensions, Weight and Resistance of Solid and Stranded Circular Conductors.*

Nominal Area.	Calculated Area.	Number and Diameter (In.) of Wires comprising Conductor.	Overall Diameter of Conductor.	Weight Per 1 000 Yards of Conductor.	Resistance per 1 000 Yds. at 60° F. (15·6° C.). Standard.	Maximum Allowable for Plain Wires.	Maximum Allowable for Tinned Wires.
1.	2.	3.	4.	5.	6.	7.	8.
Sq. In.	Sq. In.		In.	Lb.	Ohms.	Ohms.	Ohms.
0·001	0·001018	1 / ·036	0·036	11·77	23·59	24·29	24·58
0·0015	0·001521	1 / ·044	0·044	17·58	15·79	16·26	16·42
0·002	0·001943	3 / ·029	0·062	23·37	12·36	12·61	12·85
0·003	0·002994	3 / ·036	0·078	36·02	8·019	8·180	8·260
0·003	0·003217	1 / ·064	0·064	37·20	7·463	7·687	7·761
0·0045	0·004546	7 / ·029	0·087	54·39	5·281	5·387	5·493
0·007	0·007005	7 / ·036	0·108	83·81	3·427	3·496	3·530
0·01	0·01046	7 / ·044	0·132	125·2	2·294	2·340	2·363
0·0145	0·01462	7 / ·052	0·156	174·9	1·643	1·675	1·692
0·0225	0·02214	7 / ·064	0·192	264·9	1·084	1·106	1·117
0·03	0·02 ·40	19 / ·044	0·220	340·4	0·8468	0·8637	0·8721
0·04	0·03960	19 / ·052	0·260	475·5	0·6063	0·6184	0·6244
0·06	0·05999	19 / ·064	0·320	720·3	0·4002	0·4082	0·4122
0·075	0·07592	19 / ·072	0·360	911·6	0·3162	0·3225	0·3257
0·1	0·1009	19 / ·083	0·415	1 211·0	0·2380	0·2427	0·2451
0·12	0·1168	37 / ·064	0·448	1 403·0	0·2056	0·2097	0·2118
0·15	0·1478	37 / ·072	0·504	1 776·0	0·1625	0·1657	0·1673
0·2	0·1964	37 / ·083	0·581	2 360·0	0·1223	0·1247	0·1259
0·25	0·2465	37 / ·093	0·651	2 963·0	0·09738	0·09933	0·1003
0·3	0·3024	37 / ·103	0·721	3 635·0	0·07939	0·08098	0·08177
0·4	0·4064	61 / ·093	0·837	4 886·0	0·05908	0·06026	0·06085
0·5	0·4985	61 / ·103	0·927	5 994·0	0·04816	0·04913	0·04961
0·6	0·6062	91 / ·093	1·023	7 290·0	0·03961	0·04040	0·04079
0·75	0·7435	91 / ·103	1·133	8 942·0	0·03229	0·03294	0·03326
0·85	0·8459	127 / ·093	1·209	10 175·0	0·02838	0·02895	0·02923
1·0	1·0376	127 / ·103	1·339	12 481·0	0·02314	0·02360	0·02383

TABLE II.—*Comparison between the Old Standard Sizes of Conductors and the New Standard Sizes set out in B.S.S. No.* 7.

New Standard.		Old Standard.	
New Nominal Area in Sq. In.	Number and Diameter (In.) of Wires comprising Conductor.	Number and Gauge or Diameter (In.) of Wires in Conductor.	Old Nominal Area in Sq. In.
1.	2.	3.	4.
0·001	1 / ·036	1 / 20 S.W.G.	0·001
0·0015	1 / ·044		
		1 / 18 ,,	0·0018
		3 / 22 ,,	0·0018
0·002	3 / ·029		
		7 / 25 ,,	0·0022
0·003	3 / ·036	3 / 20 ,,	0·003
		7 / 23 ,,	0·0031
0·003	1 / ·064	1 / 16 ,,	0·0032
		7 / 22 ,,	0·0042
0·0045	7 / ·029		
		7 / 21½ ,,	0·0049
0·007	7 / ·036	7 / 20 ,,	0·007
		7 / 19 ,,	0·0086
0·01	7 / ·044		
		7 / 18 ,,	0·0125
0·0145	7 / ·052		
		7 / 17 ,,	0·017
0·0225	7 / ·064	7 / 16 ,,	0·022
0·03	19 / ·044		
		19 / 18 ,,	0·034
		7 / 14 ,,	0·035
0·04	19 / ·052		
		19 / 17 ,,	0·046
0·06	19 / ·064	19 / 16 ,,	0·06
0·075	19 / ·072	19 / 15 ,,	0·075
		19 / 14 ,,	0·094
0·1	19 / ·083		
0·12	37 / ·064	37 / 16 ,,	0·117
		19 / 13 ,,	0·125
0·15	37 / ·072	37 / 15 ,,	0·15
		37 / 14 ,,	0·182
0·2	37 / ·083	37 / ·083″	0·2
0·25	37 / ·093	37 / ·092″	0·25
0·3	37 / ·103	37 / ·104″	0·3
0·4	61 / ·093	61 / ·092″	0·4
0·5	61 / ·103	61 / ·104″	0·5
0·6	91 / ·093	61 / ·112″	0·6
0·75	91 / ·103	91 / ·101″	0·75
0·85	127 / ·093		
1·0	127 / ·103	127 / ·101″	1·0

TABLE III.—*Flexible Cables: Dimensions and Resistance of Conductors.*

Number and Diameter of Wires comprising Conductor.					Resistance per 1 000 Yards at 60° F. (15·6° C.).		
Nominal Area. 1.	Diameter 0·010 In. 2.	Diameter, 0·012 In. 3.	Diameter, 0·018 In. 4.	Diameter, 0·029 In. 5.	Standard 6.	Maximum Allowable for Plain Wires. 7.	Maximum Allowable for Tinned Wires. 8
Sq In.					Ohms.	Ohms.	Ohms.
0·01	140 / ·010	97 / ·012*	—	—	2·29	2·34	2·39
0·0145	195 / ·010	—	60 / ·018*	—	1·64	1·68	1·71
0·0225	296 / ·010	—	91 / ·018*	—	1·08	1·11	1·13
0·03	—	266 / ·012	117 / ·018*	—	0·847	0·864	0·881
0·04	—	368 / ·012	163 / ·018*	—	0·606	0·618	0·631
0·06	—	557 / ·012	248 / ·018*	—	0·400	0·408	0·416
0·075	—	705 / ·012	313 / ·018	121 / ·029*	0·316	0·323	0·329
0·1	—	—	416 / ·018	160 / ·029*	0·238	0·243	0·247
0·12	—	—	482 / ·018	186 / ·029*	0·206	0·210	0·214
0·15	—	—	610 / ·018	235 / ·029*	0·163	0·166	0·169
0·2	—	—	810 / ·018	312 / ·029*	0·122	0·125	0·127
0·25	—	—	1 017 / ·018	392 / ·029*	0·0974	0·0993	0·101
0·3	—	—	—	481 / ·029	0·0794	0·0810	0·0826
0·4	—	—	—	646 / ·029	0·0591	0·0603	0·0614
0·5	—	—	—	792 / ·029	0·0482	0·0491	0·0501

* For trailing cables and similar purposes.

NOTE.—The areas of the conductors in Table III. are given in nominal figures, an addition having been made to the number of wires to give resistances as nearly as possible corresponding to those for the same areas in Table I.

TABLE IV. — *Vulcanised Rubber Cables: Current-carrying Capacity (Subject to Voltage Drop) and Corresponding Fall in Pressure.*

Nominal Area of Conductor. 1.	Number and Diameter (In.) of Wires comprising Conductor. 2.	Single Cables Run in Pairs. 3.	Concentric or Twin Cable. 4.	Three-core Cable. 5.	Approximate Total Length in Circuit (Lead Plus Return) for 1-Volt Drop.* 6.
Sq. In.		Amps.	Amps.	Amps.	Ft.
0·001	1 / ·036	4·1	4·1	4·1	30
0·0015	1 / ·044	6·1	6·1	6·1	30
0·002	3 / ·029	7·8	7·8	7·8	30
0·003	3 / ·036	12·0	12·0	12·0	29
0·003	1 / ·064	12·9	12·9	12·9	29
0·0045	7 / ·029	18·2	17·5	16·0	28
0·007	7 / ·036	24·0	22·0	19·5	33
0·01	7 / ·044	31·0	26·0	23·3	39
0·0145	7 / ·052	37·0	31·0	27·0	45
0·0225	7 / ·064	46·0	38·5	33·0	55
0·03	19 / ·044	53·0	45·0	39·0	61
0·04	19 / ·052	64·0	53·0	47·0	71
0·06	19 / ·064	83·0	69·0	61·0	83
0·075	19 / ·072	97·0	80·0	71·0	90
0·1	19 / ·083	118·0	96·0	87·0	98
0·12	37 / ·064	130·0	108·0	99·0	103
0·15	37 / ·072	152·0	125·0	115·0	112
0·2	37 / ·083	184·0	150·0	140·0	123
0·25	37 / ·093	214·0	176·0	165·0	132
0·3	37 / ·103	240·0	200·0	—	145
0·4	61 / ·093	288·0	244·0	—	162
0·5	61 / ·103	332·0	280·0	—	172
0·6	91 / ·093	384·0	—	—	181
0·75	91 / ·103	461·0	—	—	185
0·85	127 / ·093	512·0	—	—	190
1·0	127 / ·103	595·0	—	—	200

* With maximum permissible current (Col. 3).

NOTE TO TABLE IV.

The current ratings given in Table IV. apply to cables employed in the wiring of buildings. They do not purport to be applicable to every condition under which cables may be used.

The figures given in the Table apply to single cables run in pairs in iron conduits or in wood casing, and to single cables sheathed with tough rubber compound, and to concentric, twin, and three-core cables of any finish run singly.

The maximum permissible currents (subject to voltage drop) for the various sizes of conductors up to 1 sq. in. in cross-sectional area are shown in columns 3, 4 and 5 of the Table, which allow for a rise in temperature of 20° F. (11·1° C.) for rubber-insulated cables. For single cables of sizes below 0· 007 sq. in. the Table is based on a current density of 4 000 amps. per sq. in.

The Table refers to situations where the temperature of the air does not exceed 80° F. (26·6° C.), and thus the normal maximum running temperature is 100° F. (37·7° C.). Rubber-insulated cables should not be allowed to attain a temperature higher than 120° F. (48·8° C.) for long periods, or for a short period 130° F. (54·4° C.). The figures, therefore, in the latter case allow of a margin of 30° F. (16·7° C.).

Where the temperature of the air exceeds 80° F. (26·6° C.), the permissible current should be reduced so that the maximum temperature of the rubber-insulated cables does not exceed the figures given above.

The further limitation of the size of conductor by the permissible drop in voltage is dealt with in Regulation 74A (*a*).

TABLE V.—*Impregnated-paper and Lead-covered Cables: Current-carrying Capacity (Subject to Voltage Drop) and Corresponding Fall in Pressure.*

Nominal Area of Conductor.	Number and Diameter (In.) of Wires comprising Conductor.	Single Cables Run in Pairs.	Concentric or Twin Cable.	Three-core Cable.	Approximate Total Length in Circuit (Lead Plus Return) for 1-Volt Drop.*
1.	2.	3.	4.	5.	6.
Sq. In.		Amps.	Amps.	Amps.	Ft.
0·001	1 / ·036	4·1	4·1	4·1	30
0·0015	1 / ·044	6·1	6·1	6·1	30
0·002	3 / ·029	7·8	7·8	7·8	30
0·003	3 / ·036	12·0	12·0	12·0	29
0·003	1 / ·064	12·9	12·9	12·9	29
0·0045	7 / ·029	18·2	18·0	18·0	28
0·007	7 / ·036	28·0	25·0	23·0	27
0·01	7 / ·044	42·0	35·0	31·5	27
0·0145	7 / ·052	57·0	45·0	41·0	28
0·0225	7 / ·064	75·0	60·0	56·0	32
0·03	19 / ·044	87·0	71·0	66·0	35
0·04	19 / ·052	104·0	85·0	78·0	41
0·06	19 / ·064	135·0	114·0	101·0	48
0·075	19 / ·072	157·0	130·0	117·0	52
0·1	19 / ·083	191·0	157·0	142·0	57
0·12	37 / ·064	210·0	174·0	161·0	60
0·15	37 / ·072	246·0	200·0	186·0	65
0·2	37 / ·083	296·0	242·0	227·0	72
0·25	37 / ·093	343·0	280·0	265·0	78
0·3	37 / ·103	385·0	322·0	304·0	85
0·4	61 / ·093	464·0	394·0	—	95
0·5	61 / ·103	540·0	457·0	—	100
0·6	91 / ·093	624·0	—	—	105
0·75	91 / ·103	738·0	—	—	109
0·85	127 / ·093	815·0	—	—	116
1·0	127 / ·103	932·0	—	—	121

* With maximum permissible current (Col. 3).

NOTE TO TABLE V.

The current ratings given in Table V. apply to cables used in the wiring of buildings. They do not purport to be applicable to every condition under which cables may be used.

The figures given in the Table apply to single cables run in pairs and to concentric, twin and three-core cables run singly.

The maximum permissible currents (subject to voltage drop) for the various sizes of conductors up to 1 sq. in. in cross-sectional area are shown in columns 3, 4 and 5 of the Table, which allows for a rise in temperature of 50° F. (27·7° C.) for impregnated-paper cables. For single cables of sizes below 0·0145 sq. in. the Table is based on a current density of 4 000 amps. per sq. in.

The Table refers to situations where the temperature of the air does not exceed 80° F. (26·6° C.) and thus the normal maximum running temperature is 130° F. (54·4° C.). Impregnated-paper lead-covered cables for pressures not exceeding 660 volts should not be allowed to attain a permanent temperature higher than 176° F. (80° C.) and the figures therefore allow of a margin of 46° F. (25·6° C.).

Where the temperature of the air exceeds 80° F. (26·6° C.), the permissible current should be reduced so that the maximum temperature of the impregnated-paper lead-covered cables does not exceed the figures given above.

The further limitation of the size of conductor by the permissible drop in voltage is dealt with in Regulation 74A (*a*).

TABLE VI.—*Rubber-insulated Flexible Cables for use with Portable Appliances: Current-carrying Capacity.*

Nominal Area of Conductor.	Number and Diameter (In.) of Wires comprising Conductor.	Maximum Current Permissible (subject to Voltage Drop).	
		Two Conductor.	Three Conductor.
1.	2.	3.	4.
Sq. In.		Amps.	Amps.
0·01	140 / ·010	20	17
0·0145	195 / ·010	24	20
0·0225	296 / ·010	30	25
0·03	266 / ·012	35	30
0·04	368 / ·012	42	35

NOTE.—Where the outer sheathing of a flexible cable is independently gripped so as to prevent any stress coming on the conductors of the cable and the terminals of the apparatus to which it is connected, the current ratings given in columns 3 and 4 of Table VI. may be increased to those set out in columns 4 and 5 respectively of Table IV. for a vulcanised rubber cable of the same nominal area.

An earth wire, whether insulated or not, forming part of a flexible cable is not regarded as a conductor for the purposes of this Table.

TABLE VII.—*Flexible Cords: Dimensions and Resistance of Conductors.*

Nominal Area.	Ordinary Flexible Cords..				Flexible Cords with Tough Rubber Sheathing.		
	Number and Diameter (In.) of Wires comprising Conductor.	Resistance Per 1 000 Yds. at 60° F. (15·6° C.).*			Number and Diameter (In.) of Wires comprising Conductor.	Resistance Per 1 000 Yds. at 60° F. (15·6° C.).*	
		Standard.	Maximum Allowable for Plain Wires.	Maximum Allowable for Tinned Wires.		Standard.	Maximum Allowable.
1.	2.	3.	4.	5.	6.	7.	8.
Sq. In.		Ohms.	Ohms.	Ohms.		Ohms.	Ohms.
0·0006	14 / ·0076	39·7	40·5	41·3	7 / ·012 †	40·5	41·3
0·001	23 / ·0076	24·2	24·6	25·1	11 / ·012 ‡	24·6	25·1
0·0017	40 / ·0076	13·9	14·2	14·4	16 / ·012 §	14·2	14·4
0·003	70 / ·0076	7·94	8·10	8·26	28 / ·012 §	8·10	8·26
0·0048	110 / ·0076	5·05	5·15	5·25	44 / ·012 §	5·15	5·25
0·007	162 / ·0076	3·43	3·50	3·57	65 / ·012 §	3·50	3·57

* The figures given for resistance refer to straight single conductors. Where these are twisted into twin or multicore cords the resistance of each conductor must be increased by 5 per cent. to allow for the extra length due to laying up.

† 5 tinned copper; 2 tinned steel. ‡ 9 tinned copper; 2 tinned steel.

§ All tinned copper.

TABLE VIII.—*Flexible Cords; Thickness of Insulation and Current-carrying Capacity.*

Nominal Area of Conductor.	Ordinary Flexible Cords.					Flexible Cords with Tough Rubber Sheathing of a Minimum Thickness of 0·05 In.*			Maximum Current Permissible (Subject to Voltage Drop).
	Number and Diameter (In.) of Wires comprising Conductor.	Minimum Thickness of Dielectric.				Number and Diameter (In.) of Wires comprising Conductor.	Overall Diameter.		
		High Insulation (Kind 1).		Medium Insulation (Kind 2).					
		Pure Rubber.	Pure and Vulcanising Rubber	Pure Rubber.	Vulcanising Rubber.		250 Volts.	660 Volts.	
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Sq. In.		In.	In.	In.	In.		In.	In.	Amps.
0·0006	14 / ·0076	0·020	0·033	0·015	0·028	7 / ·012	0·202	0·246	1·8
0·001	23 / ·0076	0·020	0·034	0·015	0·029	11 / ·012	0·216	0·258	3·0
0·0017	40 / ·0076	0·020	0·035	0·015	0·030	16 / ·012	0·227	0·269	5·0
0·003	70 / ·0076	0·020	0·036	0·015	0·031	28 / ·012	0·248	0·290	8·5
0·0048	110 / ·0076	0·020	0·038	0·015	0·032	44 / ·012	0·268	0·308	13·0
0·007	162 / ·0076	0·020	0·039	—	—	65 / ·012	0·290	0·330	17·0

* A thickness of 0·030 in. is permissible in the case of twin flexible cord having conductors insulated with pure and vulcanising rubber and twisted together and sheathed overall with tough rubber, for pendant electric light fittings up to 250 volts.

NOTE.—An earth wire, whether insulated or not, forming part of a flexible cord is not regarded as a conductor for the purposes of this Table.

INDEX.

PRINTED IN GREAT BRITAIN BY
THE ABERDEEN UNIVERSITY PRESS, ABERDEEN